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The Platte River Ecology Study

Special Research Report

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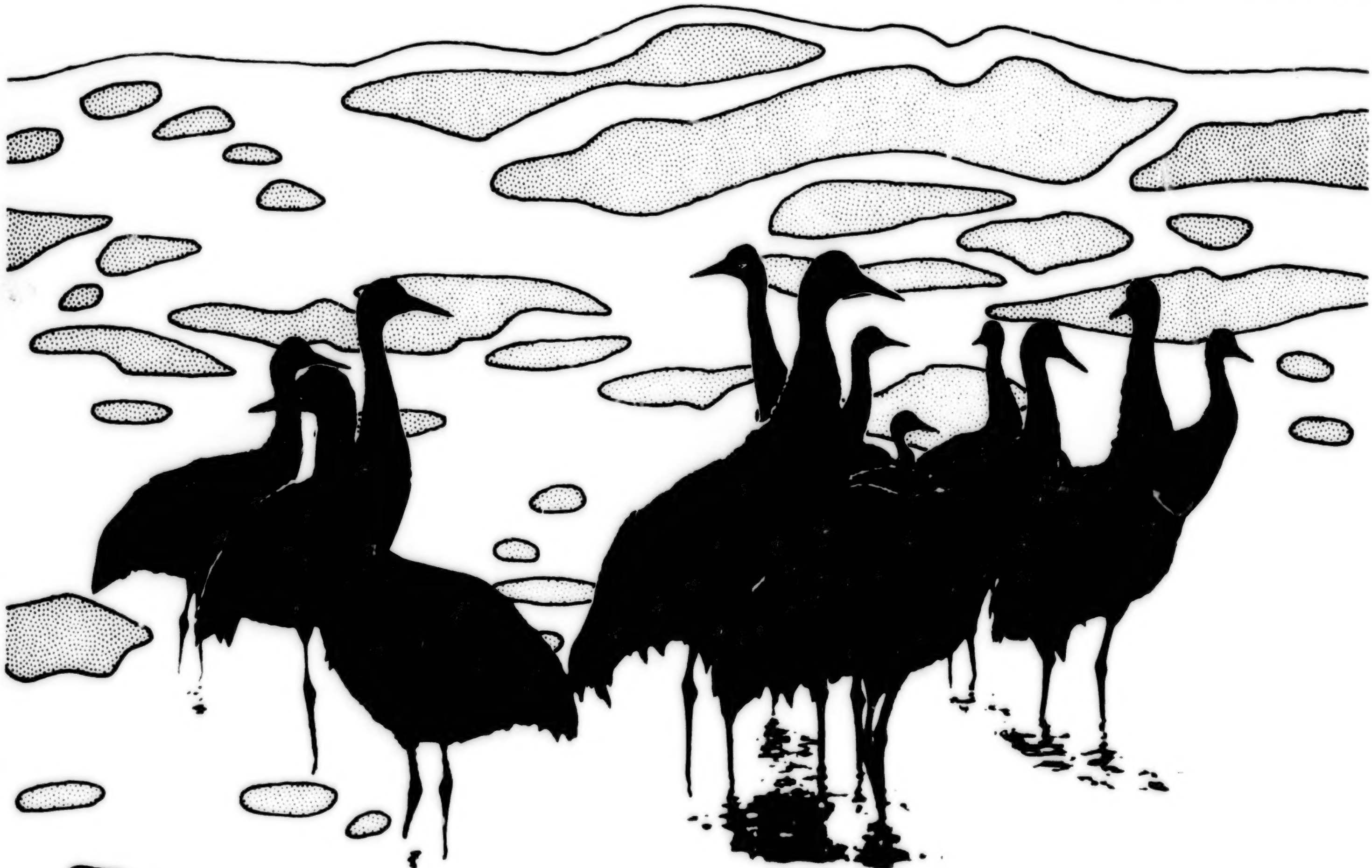

Fish and Wildlife Service

U.S. Department of the Interior

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THE PLATTE RIVER ECOLOGY STUDY

SPECIAL RESEARCH REPORT

U.S. Fish and Wildlife Service
Northern Prairie Wildlife Research Center
Jamestown, North Dakota 58401
June 1981

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SYNOPSIS

Each spring about 80% of the sandhill cranes in North America stop for several weeks in the Platte and North Platte River Valleys of Nebraska while enroute to breeding grounds in Canada, Alaska, and the Soviet Union. This concentration of cranes is unparalleled in North America and these sites represent the principal spring staging areas for the midcontinent population. Large numbers of waterfowl, numerous bald eagles, whooping cranes, and many other species also use the area.

Recent changes in habitat conditions along the Platte and North Platte Rivers have prompted concern for the welfare of sandhill cranes and other migratory birds found there. With approximately 70% of the Platte's annual flows diverted for various consumptive uses upstream in Colorado, Wyoming, and western Nebraska, channel width in many areas has been reduced to 10-20% of former size. Habitat conditions within the existing channel have also changed as a result of reduced scouring of sandbars and shifting of alluvial sediments. A broad band of mature deciduous woodland now occupies tens of thousands of acres that formerly were part of the river and numerous islands overgrown with woody vegetation exist within the channel. Concurrent with diminishing surface flows in the channel, the water table beneath adjacent native grasslands has declined, thereby facilitating extensive conversion of these sites to cropland.

In 1978, the U.S. Fish and Wildlife Service began a 3-year investigation to define habitat-use patterns and habitat requirements of migratory bird populations utilizing the North Platte and Platte River Valleys in Nebraska and to assess factors influencing woody vegetation establishment along these Rivers. Concurrent investigations were conducted by the U.S. Geological Survey and the U.S. Water and Power Resources Service to identify flows necessary to maintain desired levels of migratory bird habitat and locate potential sources of water to be utilized in habitat maintenance.

Research findings indicate that sandhill cranes occupy four discrete staging areas encompassing approximately 1037 km^2 in the Platte and North Platte River Valleys. Individual staging sites (identified by nearby towns and cities) and their size (in km^2) are as follows: Kearney-Grand Island, 578; Overton-Elm Creek, 257; Sutherland-North Platte, 184; and Lewellen, 18. Cranes typically begin to arrive in late February and some remain into late April; peak numbers are present from about 20 March to 5 April when up to approximately 500,000 cranes are present. About two-thirds of the staging population is situated along the Platte River between Kearney and Grand Island. Cranes generally remain within 1.6-3.2 km of the channel during the staging period and rarely move beyond 6.4 km from the River. Individuals average five moves per day with daily flight distance averaging about 9.7 km. During the course of the stopover period, individuals roost over about an 11.8-km reach of river; the average shift from one night to the next is about 1.6 km. The cumulative size of an individual crane's home range averages approximately 36 km^2.

Sandhill cranes utilize several habitat types in meeting their nutritional requirements. Radio-marked cranes spent approximately 55% of the daylight hours in cropland, 27% in native grassland, and 15% in hayland. In cropland, cranes feed almost exclusively on waste corn, but invertebrates (earthworms, snails, grasshoppers) constitute most of their diet in native grasslands. Both invertebrates and alfalfa leaves and stems are consumed in haylands. About 96% of the total daily intake of foods (dry weight basis) comes from cornfields and 4% from native grasslands and hayland. Cranes do not compete with livestock for corn because cattle feed on ears whereas cranes feed primarily on scattered kernels. The birds forage for invertebrates to secure certain essential nutrients either lacking or present in low levels in corn. Ingestion of animal matter balances the diet by supplying certain amino acids and minerals. Calcium needs are met from snail shells and from concretions unearthed in the calcareous loess soils on native grasslands.

The Platte River Valley is a major fat deposition site for the midcontinent sandhill crane population. It is estimated that over 90% of the fat accumulated during the staging period is derived from corn. Males and females deposit fat at daily rates of 13.2 g and 9.1 g, respectively, during the stopover period. The amount of fat stored varies directly with the length of time individuals stay at the Platte. Approximately 40% of the fat reserves are utilized during the long migration; most of the remaining reserves sustain the birds during the nesting season.

The food requirements of the sandhill crane population are substantial; estimated daily food intake ranged from about 0.3 metric tons of corn on 1 March to 57.3 metric tons on 31 March. The cumulative corn intake for projected populations of 350,000 and 450,000 cranes was estimated to be 1023 and 1315 metric tons. Current harvesting techniques leave approximately 6-7% of the corn crop in the fields; cattle consume approximately half of that during the fall and winter months. At current population levels, cranes utilize 10-20% of the corn available when they arrive. Corn availability is adequate to meet the population's current energy requirements; however, the near total dependence on corn for this purpose causes the population to be vulnerable to food shortages if land use changes.

The "Big Bend" reach of the Platte River historically received relatively high use by whooping cranes during migration. This reach continues to be used, but at markedly lower levels than in former periods. Habitat degradation associated with channel shrinkage is probably a major cause of this decline. Whooping cranes roost in broad reaches of river channel with most documented use occurring at sites between 155 and 365 m wide. Foraging occurs in a variety of habitats but agricultural lands receive the highest use. The whooping crane, like the sandhill crane, ingests both plant and animal matter during migration.

Thousands of mallards and Canada geese spend each winter in the Platte River Valley. The birds gather at ice-free sites along the River, particularly between Lexington and Grand Island. In late winter, large populations of white-fronted geese, pintails, and certain other species of waterfowl also gather along the Platte River; these early migrants and the overwintering birds move into the rainwater basins as ponds open in spring. Habitat use by mallards during winter varied with the severity of weather conditions. Mallards spent most of their time in the river channel during favorable weather but shifted to nearby canals during adverse conditions. Mortality was substantial during periods of heavy snow and ice cover as ducks fell prey to raptors confronted with diminishing alternative prey. Mallards obtained most of their winter diet from cornfields; corn accounted for 97% and 94% of the diets of drakes and hens, respectively. The birds were dependent on livestock to uncover food supplies when snow cover was heavy; prolonged feeding flights and reduced physical condition resulted from diminished foraging opportunities. Although mallard nutritional requirements during winter were met largely from plant foods taken in cropland, small amounts of animal matter were ingested during prolonged feeding periods in riverine wetland habitat. The diet of migrant mallards during the spring staging period changed only slightly from winter.

Most of the midcontinent population of white-fronted geese spend several weeks in south central Nebraska during spring. The population utilizes the area to prepare physiologically for migration and reproduction. The birds rely primarily upon the abundant supply of waste corn to meet maintenance energy requirements and for fat storage. Corn accounted for 77% and 91% of the diet of adult males and females; green shoots of winter wheat formed the other principal component of the diet. Male and female geese acquired fat at a daily rate of 12.5 and 17.6 g, respectively, while staging on the study area.

The presence of extensive tracts of woodland in the Platte and North Platte River Valleys during recent times probably has benefited several species of raptors. Sixteen species of raptors were observed during the study, including the endangered bald eagle and peregrine falcon. The bald eagle was the most numerous raptor; peak wintering populations were estimated to be 150 and 250 birds during the 1978-79 and 1979-80 winters. The other principal raptors, in declining order of abundance, were the red-tailed hawk, American kestrel, marsh hawk, rough-legged hawk, prairie falcon, ferruginous hawk, and golden eagle. Densities of raptors along established survey routes were 0.46 birds/km in the winter of 1978-79 and 0.39 during 1979-80.

Bald eagles are a common winter resident of the Platte and North Platte River Valleys. Discharges from Kingsley Dam and return flows from the Tri-County Diversion Canal keep certain reaches of the river ice-free during winter, a condition which attracts a sizable overwintering mallard population and allows eagles access to fish. Fish and mallards were major prey of bald eagles wintering along the Platte. Bald eagles occurred throughout the entire 327 km of river under study, but densities varied widely, probably in response to varying food availability; nine roosts were located between Kingsley Dam and Chapman. The diet of eagles was diverse; 23 species of birds and 22 species of mammals were identified from 2858 regurgitated pellets. Eagle food habits were strongly influenced by prey availability; mallards became a major prey during periods when fish were not available because of ice cover or water depth. Most mallards occurring in the eagle diet apparently were pirated from other raptors.

The breeding avifauna of the Platte and North Platte River Valleys and adjacent lands is diverse. A total of 142 species of birds, representing approximately 70% of the species that nest in Nebraska, were recorded breeding on the study area during 1979 and 1980. Thirty-four species accounted for approximately 95% of the total population. Species which nest in riparian woodland habitat have increased markedly because of the presence of extensive woodlands in the former channel of the Platte and North Platte Rivers. The least tern and piping plover nest on open sandbars at sites protected by a water barrier; diminished flows have caused elimination of much of their nesting habitat and the numbers of pairs of both species have declined accordingly. The replacement of about 70% of the native grassland of the Valley with cropland has brought on a corresponding reduction in the abundance of species which breed in grassland, including the upland sandpiper, bobolink, and grasshopper sparrow. Species diversity and density of breeding pairs were high on river channel islands and in lowland forests, moderate on native grassland, and low on alfalfa hayland and cropland.

Analyses of annual tree rings and other data indicate woody vegetation encroachment on the channel occurred principally after Kingsley Dam on the North Platte River and the Tri-County Diversion Canal on the Platte River became operational during the early 1940's. West of Overton, since 1950, woody vegetation development in riparian woodlands has been confined primarily to the establishment of understory red cedar, willow, and Russian olive. Between Overton and Chapman, the only reach where cranes still stage along the Platte River, substantial encroachment by cottonwood and willow has occurred during the past 30 years. Cottonwood and willow invasion of channel habitat represents the most immediate threat to continued use of the river channel by cranes. The extent of woody vegetation establishment in the channel each year varies with magnitude of flows during the summer months when seed dispersal is in progress. Cottonwoods and willows usually release their seeds during June and July. After release, cottonwood and willow seeds remain viable for about 20 and 10 days, respectively. Seedling establishment by these species generally occurs on fine textured soils with a high percentage of moisture and a long substrate exposure period. After becoming established, if the seedlings grow to a height of 15 cm, which can readily occur during the first growing season, the plants can withstand prolonged inundation the following spring. Therefore, maintenance of adequate flows during the summer months to prevent seed germination and seedling establishment represents the most effective means of controlling woody vegetation encroachment in the channel.

Sandhill cranes roost in the shallows and on sandbars in the river channel. These birds prefer roosting in areas where the channel is at least 150 m wide, and strongly avoid river channels narrower than 50 m. The height of vegetation along river banks and on islands influences the selection of roosting areas when unobstructed channel width falls below 150 m; the presence of a bridge or a road adjacent to the channel also reduces use. Of 406 0.8 km segments of river channel within the study area, 137 (34%) were utilized as roost sites in 1979. Crane densities at 18% of the sites exceeded 5000 individuals/0.8 km. The loss of about two-thirds of the original roosting habitat between Kingsley Dam and

Grand Island has caused crowding at remaining roost sites, thereby increasing crane susceptibility to catastrophic losses from natural forces, particularly severe storms and disease. Four diseases with epizootic potential have been reported in migratory birds either on the study area or within populations that occur there; these are botulism, duck plague, avian cholera, and aspergillosis. Heavy losses of several species of waterfowl to avian cholera occurred in the Rainwater Basin Area a few miles from crane staging areas during the period of study; in 1980, 30,677 dead waterfowl were retrieved from the disease die-off area.

Native grasslands, river channel, and cropland each serve a vital role in maintaining sandhill crane use of the Platte and North Platte River Valleys. Both native grassland and channel habitats are threatened by declining flows. The rapid rate of attrition of native meadows, where cranes obtain much of their protein and calcium, poses an immediate concern. Prompt action is needed to protect key grassland tracts near the channel. Crane requirements are well suited to a habitat maintenance plan that protects tracts of moderate to small size spaced a few miles apart along those reaches of the two Rivers that cranes still inhabit, instead of creating a large refuge near Grand Island as originally proposed. Additional protection, possibly through easements, will be needed to maintain existing land use practices on other native grassland tracts near the channel between the managed reserves. Maintenance of an unobstructed river channel width of 150 m at sites within existing staging areas is adequate to satisfy roost-site requirements of the sandhill crane population during the staging period.

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PREFACE

This report summarizes findings of the Platte River Ecology Study. The 3-year investigation was conducted by the U.S. Fish and Wildlife Service to 1) determine the role of the Platte River Valley in contributing to the requirements of midcontinent migratory bird populations and 2) develop guidelines for management of riverine habitats and adjacent lands supporting populations of selected species of migratory birds.

A research team formed by investigators from the U.S. Fish and Wildlife Service and several universities conducted the study. Individual investigations focused principally on various aspects of migratory bird usage of the Platte River Valley and on factors affecting habitat conditions on riparian lands.

Nearly all facets of the research program described in this report will be submitted for publication in scientific journals. Readers requiring a more detailed description of individual studies should consult the technical papers that will be forthcoming.

Gary L. Krapu
Project Leader

MAJOR CONTRIBUTORS TO THE REPORT

The sandhill crane received the most attention in these investigations because of widespread concern for its well-being as a result of marked change in habitat conditions during recent decades in the Platte River Valley. The distribution and abundance of sandhill cranes were determined from aerial and ground surveys. Ed Ferguson, Flyway Biologist of the Office of Migratory Bird Management, developed a photographic census technique to estimate population size. Chuck Frith visually estimated number of cranes in the channel by 0.8 km (0.5 mile) segment during early morning aerial surveys, and Craig Faanes compiled the visual estimates made by a ground survey team to delineate crane diurnal distribution in the Platte River Valley. Home-range characteristics and habitat-use patterns of sandhill cranes were determined with the aid of radio-telemetry. Gary Krapu, Erik Fritzell, Wayne Norling, and Mia Hay participated in these investigations. Crane feeding ecology, fat deposition, and population energy requirements were studied by Ken Reinecke and Gary Krapu. Cheryl Boise collected data on cranes in Alaska.

Information on whooping crane use of the Platte River Valley was prepared by Kurt Johnson and is based on findings from his research supported through the Office of Endangered Species as part of a Master's degree program at the University of Wisconsin-Madison.

Waterfowl investigations focused principally on studies of mallards and white-fronted geese. The research on winter and spring staging ecology of mallards was conducted by Dennis Jorde, a candidate for a Master of Science Degree at the University of North Dakota. Mia Hay and John Cochnar assisted in these investigations. Information on food habits and fat deposition in white-fronted geese were collected by Gary Krapu, Dennis Jorde, Ken Reinecke, and Riley Atkins.

Raptor investigations dealt principally with the distribution of wintering raptors in the Platte and North Platte River Valleys and the feeding ecology of bald eagles; both studies were conducted by Gary Lingle. Craig Faanes conducted the studies on breeding birds. Wayne Norling assisted in both raptor and breeding bird research.

Research on vegetation, including development of a habitat classification system and studies of factors controlling establishment of woody vegetation, was conducted by Paul Currier, a doctoral candidate in plant ecology at Iowa State University, and Russell Kologiski. Dick Pillmore was responsible for interpretation and preparation of detailed maps depicting habitat conditions along each reach of the 203-mile river channel from Kingsley Dam to Chapman.

Gary Krapu served as project leader for the Platte River Ecology Study and supervised preparation of the Special Research Report. Doug Facey was employed under the Cooperative Ecological Internship Program between the U.S. Fish and Wildlife Service and the Institute of Ecology to help facilitate preparation of the Report. He also participated in research on roost-site selection by sandhill cranes and in development of a detailed inventory of habitat conditions on crane staging areas.

Chuck Frith, in addition to participating in research, was stationed at Grand Island and coordinated field research planning efforts between the research team, landowners, and various other entities in Nebraska.

Mavis Meyer and Mia Hay prepared most of the drawings presented in the Report. Mavis Meyer, Ray Thielman, and Gary Krapu developed the cover design for the Report.

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U.S. Fish and Wildlife Service

We acknowledge numerous individuals employed by the U.S. Fish and Wildlife Service for their assistance in bringing this project to a successful completion. In particular, we thank W. Reid Goforth, Director of the Northern Prairie Wildlife Research Center and Dave Trauger, Assistant Director, during their tenures and Rey Stendell, Acting Director for the remaining term of the study for their support and encouragement. Doug Johnson, Supervisor of Statistical Services at the Center, Tony Frank, Al Davenport, Carol Nustad, and Sandy Harris are thanked for their prompt handling and processing of the large data bank that accumulated during the course of these investigations. We are indebted to Pat Johnson, Supervisor of Clerical Services and to her staff, in particular Debra Reimers and Tammy Fercho, for their prompt and conscientious typing of several drafts of the Report. Carole Hayes, Administrative Assistant at the Center, was most helpful in facilitating numerous transactions involving contracts, purchase of equipment and supplies. Eileen Bartels, Center Librarian is thanked for her assistance in obtaining numerous reports and other documents sought by the research team during the course of these investigations. We acknowledge the assistance of other Center researchers, particularly Lew Cowardin and Al Sargeant, in providing equipment and facilities needed to complete our studies. We thank Center Chemist Vyto Adomaitis and Technician John Shoesmith for lipid analyses of waterfowl carcasses. We deeply appreciate the prompt attention given our needs by the Maintenance Staff and in particular Supervisor Loren Hemen and Shop Foreman Jim Romelfanger. Their conscientious attention to our many requests did much to further our studies. The Technician Pool at the Center, particularly Supervisor Charlie Shaiffer and Technicians Bruce Hanson, Larry Mechlin, Mavis Meyer, and Jim Piehl contributed immensely to the successful conduct of our research. Several employees participated in studies under part-time appointments and are acknowledged including Kim Hennings, Doug Janke, Frank Rohwer, Bob Sanford, Tom Turnow and Adrian Wydeven. Young Adult Conservation Corps employees that were involved in the project were John Cochnar, Brooks Gehring, Dave Jenson, Sara Minkoff, and Cathy House. One student, Sherri Minneman, was employed under a Cooperative Education Agreement. Volunteer assistance was provided by John Reeves.

The research team was given valuable assistance by other U.S. Fish and Wildlife Service personnel. We acknowledge the assistance and encouragement provided by Darold Walls, past Manager of the Hastings Wetland Management District, and the following members of his staff: Al Trout, Ray Washtak, and Duane Huber. Fant Martin, former Director of

the Migratory Bird and Habitat Research Laboratory, is thanked for his support in coordinating cooperative aspects of our investigations. The staff at the Ecological Services Office at Grand Island, and in particular, Supervisor Kent Kroonemeyer and Gene Miller provided much support to our field research program. The Pierre Area Office, and in particular, Area Managers Rolf Wallenstrom and Jim Salyer, Assistant Area Manager Chuck Sowards, and Biologist Maurice Anderson are acknowledged for their assistance. Assistant Regional Director Bill Martin and Biologists Dale Sutherland and Grady Towns helped coordinate our studies with other governmental entities. We thank Chris Brandt of the National Fish and Wildlife Health Laboratory for providing information on wildlife disease outbreaks. Paul Vohs, Unit Leader of the Oklahoma Cooperative Wildlife Research Unit during most of the study is acknowledged for extending the support of his personnel who were conducting crane research along the North Platte River. We are grateful for the assistance provided by Charles Strickland, Manager of the Clarence Rhode National Wildlife Range, and Chris Dau, Wildlife Biologist, stationed at the Range.

Other Agencies, Institutions, and Individuals

Several other agencies, institutions, and individuals also assisted our efforts. The Nebraska Game and Parks Commission is acknowledged for the assistance provided by the following individuals: Ken Johnson, Joe Hyland, Ross Locke, Jim Hurt, Bill Ernest, Loren Noecker, Nick Lyman, Don Schepler, and George Nason. Members of the U.S. Geological Survey participating in Platte River hydrology studies are thanked for their assistance. In particular, we appreciate the support given by Carl Nordin and Dick Hadley who served as project leaders of the Platte River hydrology study, and Lester Petri, Acting District Chief at Lincoln, Nebraska. The Bureau of Reclamation personnel assigned to Platte River studies are acknowledged for their support particularly Roger Weidleman and Terry Lynott. The Canadian Wildlife Service and especially Clint Jorgenson, Manager of the Last Mountain Lake Game Management Area, are thanked for assisting our research efforts. We are grateful to The National Audubon Society for allowing us to conduct research on their property and for the services of Bob Wicht, the Manager of the Lillian Annette Rowe Sanctuary and Gary Pearson, an expert on wildlife diseases important to migratory bird populations. Merlin W. Erickson, Agricultural Economist with the U.S. Department of Agriculture Economic and Statistics Service, is acknowledged for providing socio-economic data for counties in the study area. Robert Jarvis, Associate Professor in the Department of Fisheries and Wildlife at Oregon State University, helped facilitate crane research on the Yukon-Kuskokwim Delta in Alaska.

Numerous landowners allowed access to their properties during the course of these investigations. We are particularly indebted to the assistance provided by the following landowners: Ted Peterson, John Pierce, Art Terry, Kent Binfield, Bob Crandall, and Joel Jeffreys.

Review of Special Research Report

We gratefully acknowledge the following individuals for their critical review of the report: Ken Abraham, David Ankney, Jan Eldridge, Erik Fritzell, Hal Kantrud, and James Lewis.

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INTRODUCTION

Fresh water is among the most critical factors limiting urban growth and agricultural development in the western United States. Water development projects now impound for consumptive use much of the annual precipitation that falls in the West. Development of this resource has affected fish and wildlife resources in many areas but seldom have the potential impacts to migratory bird populations been as significant as in the Platte River Basin. With a watershed extending westward to the Continental Divide in Colorado and Wyoming, the waters of the Platte must traverse hundreds of miles of arid plains before reaching south central Nebraska. During the past century, man has developed numerous impoundments and diversion systems to tap the annual flows for irrigation and other purposes at numerous sites in the Upper Platte River Basin (Fig. 1). As a consequence, approximately 70% of the annual flows of the Platte are now withdrawn before reaching south central Nebraska (Kroonemeyer 1978). With much of its waters diverted upstream, the North Platte River downstream from Kingsley Dam, and the Platte River have undergone massive physical changes during recent decades. River channel width, for example, in some areas has diminished by 90% in the past 100 years (Williams 1978). Concurrent with channel shrinkage, extensive woodlands have become established on much of the former channel area (Fig. 2), and islands with woody vegetation now dot the river.

Changes in the character of the Platte River caused by shrinkage of the river channel and associated woody vegetation encroachment, plus the destruction of adjoining native grasslands concomitant with the decline of the water table and conversion of these lands to cropland (Fig. 3), have greatly altered habitat conditions for migratory birds. Recent habitat loss has caused concern for the welfare of the millions of migratory birds that stop along the Platte for several weeks during spring while enroute to breeding grounds on the northern plains, taiga, and arctic. Attention has been focused primarily on the potential impact of changing riverine conditions on the populations of sandhill cranes[1] and whooping cranes. The plight of the cranes and concern about water development in the Platte River Basin became a major national resource issue in the early 1970's, when plans were in progress to develop the Mid-State Irrigation Project along the Platte in south central Nebraska. This project, which would have irrigated 566.8 km^2 (218.8 mi^2) and withdrawn 363,000,000 m^3 (295,000 acre-ft) from the river in areas used by cranes, was later withdrawn following its defeat in a local referendum. Abandonment of this project, however, did not defuse the issue because numerous other plans remained which sought to divert most of the Platte's remaining waters.

In 1973, the U.S. Fish and Wildlife Service, recognizing the need to maintain habitat in the Platte River Valley to meet the needs of migratory bird populations, attempted to preserve a key area encompassing approximately 60.7 km^2 (23.4 mi^2). This site, centering on Shoemaker Island, approximately 13 km southwest of Grand Island, was to be developed as a national wildlife refuge. When unveiled, however, the plan met

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[1] A list of common and scientific names of the animal and plant species identified in this Report is provided in Appendices A and B, respectively.

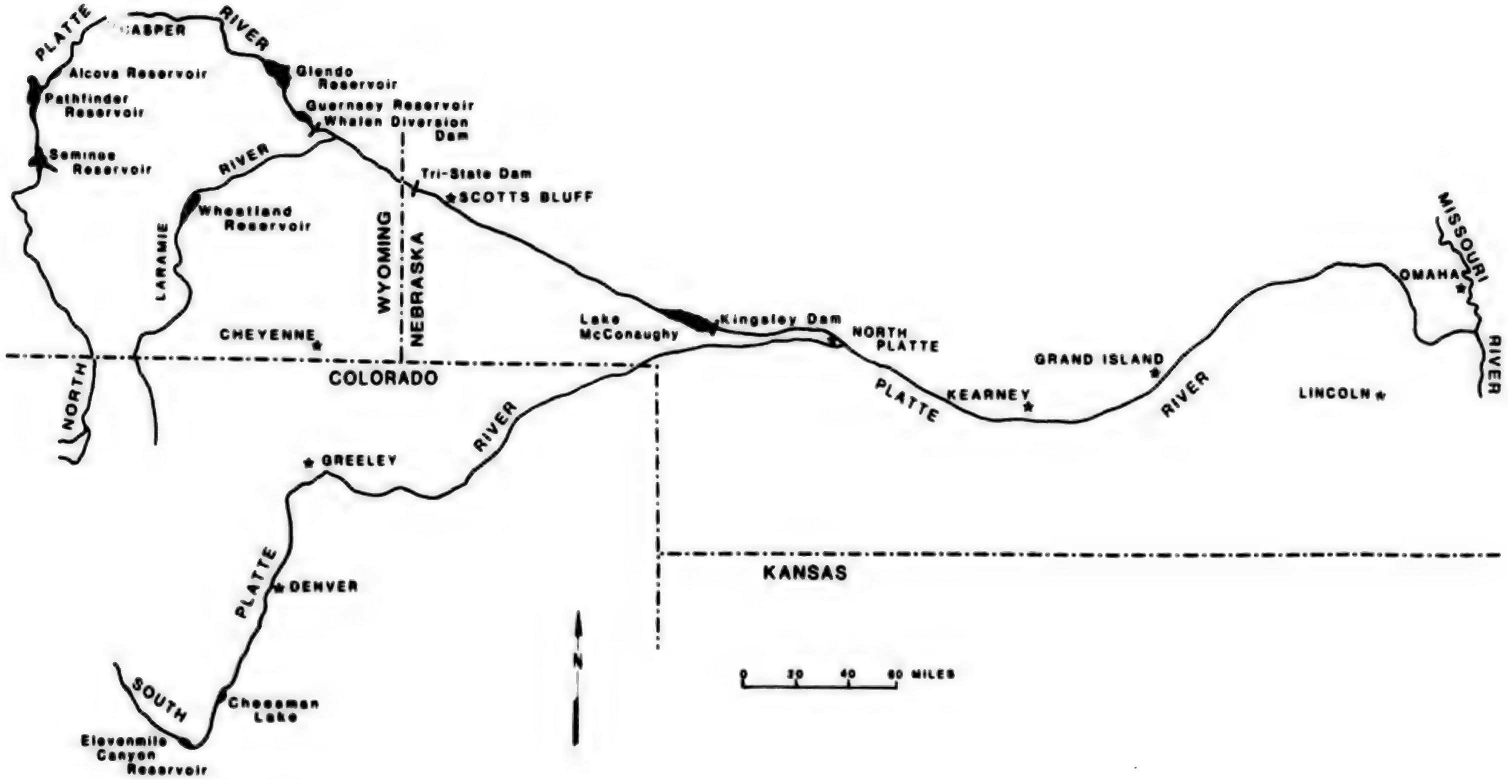

Fig. 1. Platte River drainage in Colorado, Wyoming, and Nebraska.

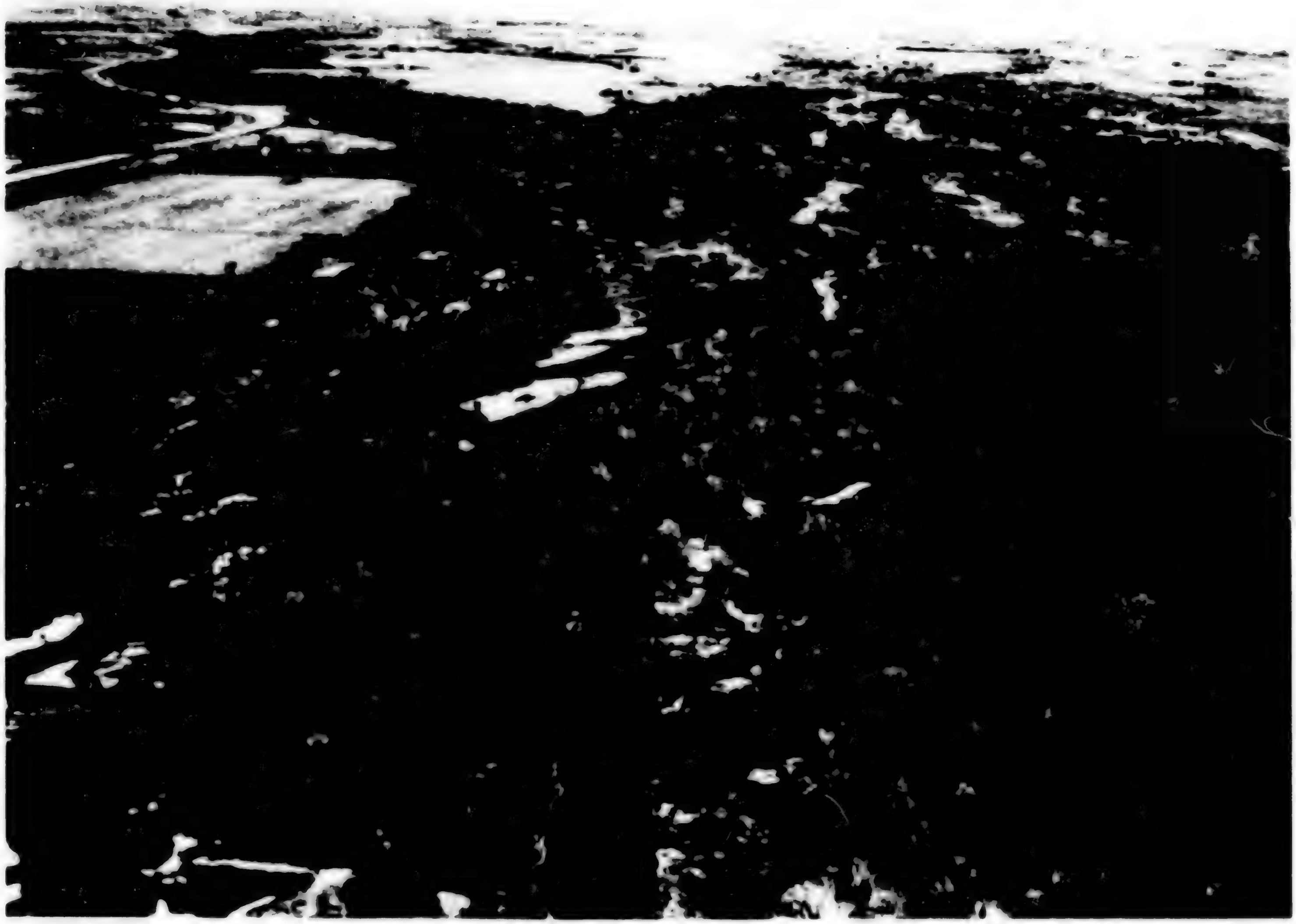

Fig. 2. Channel width in this reach of the Platte River west of Kearney in south central Nebraska has been reduced by approximately 90% during the past century and cranes no longer roost there. The area encompassed by woodland was formerly channel.

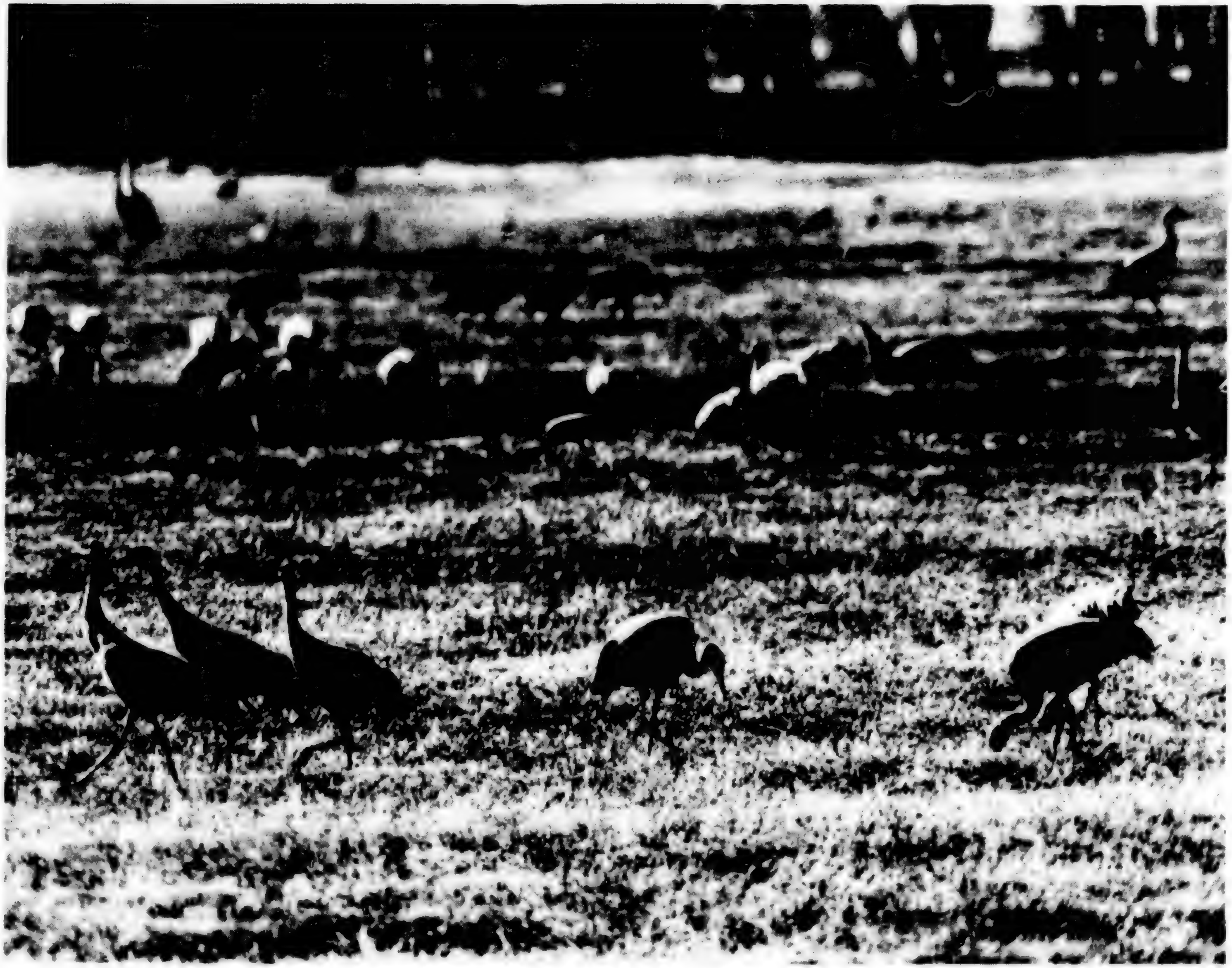

Fig. 3. Sandhill cranes foraging in a native meadow near the Platte River. Many acres of the remaining grassland habitat are lost to agriculture each year.

with strong opposition from local landowners fearing condemnation of their lands (Wallenstrom 1976) and was withdrawn. The Fish and Wildlife Service began seeking alternative approaches to preserve habitat for cranes and other migratory birds because of the continuing need to resolve issues concerning habitat preservation. As part of that process, the Service agreed to conduct a study following criteria set by the Water Resources Council to evaluate whether a refuge was needed to meet bird requirements.

Preliminary steps to develop an information package on migratory bird requirements led to recognition of the need for detailed studies to evaluate the impact of changing habitat conditions on migratory bird populations using the Valley. Although millions of migratory birds use the Platte River Valley and nearby Rainwater Basin Area annually, habitat requirements of most, including several key species such as the sandhill crane, white-fronted goose, and the endangered whooping crane and bald eagle, remained largely undetermined. The problem was made more acute by a general lack of information on the role of staging areas in the life history of sandhill cranes and waterfowl. Of particular concern was recent scientific evidence that nutrient reserves acquired before arrival on the breeding site are vital to reproduction in certain species of waterfowl (Ankney and MacInnes 1978; Raveling 1979; Drobney 1980; Krapu 1981), which suggested that staging areas such as the Platte may serve to prepare birds physiologically for reproduction.

A multidiscipline team was formed at the Northern Prairie Wildlife Research Center to develop the research program following approval of funding in October 1977. The team was given 3 years (1978-80) to complete its investigations (Fig. 4). Research has dealt principally with two major issues: (1) habitat needs of migratory bird populations, and (2) the role of Platte River flows in maintenance of habitat. The latter issue was jointly investigated with the U.S. Geological Survey conducting studies to determine water requirements necessary to sustain the habitat base identified by the U.S. Fish and Wildlife Service. The Bureau of Reclamation also participated in the joint investigations by evaluating present water use and future water needs within the Upper Platte River Basin.

Personnel from the Migratory Bird and Habitat Research Laboratory, the Migratory Bird Management Office, the Ecological Services Office at Grand Island, Nebraska, and several universities joined researchers from the Northern Prairie Wildlife Research Center in undertaking the project. Because numerous important species of migratory birds utilize the Platte River Valley, a research effort developed that was broad in scope yet thorough in its treatment of species that appeared most vulnerable to the changing habitat conditions on riparian lands. Concurrent studies described existing habitat conditions and determined factors controlling plant succession on riparian lands. These studies were followed by experiments to determine how water regimes can be manipulated to inhibit germination and prevent establishment of woody vegetation, a step needed to maintain suitable habitat for species that utilize broad open reaches of river channel, especially the sandhill and whooping cranes.

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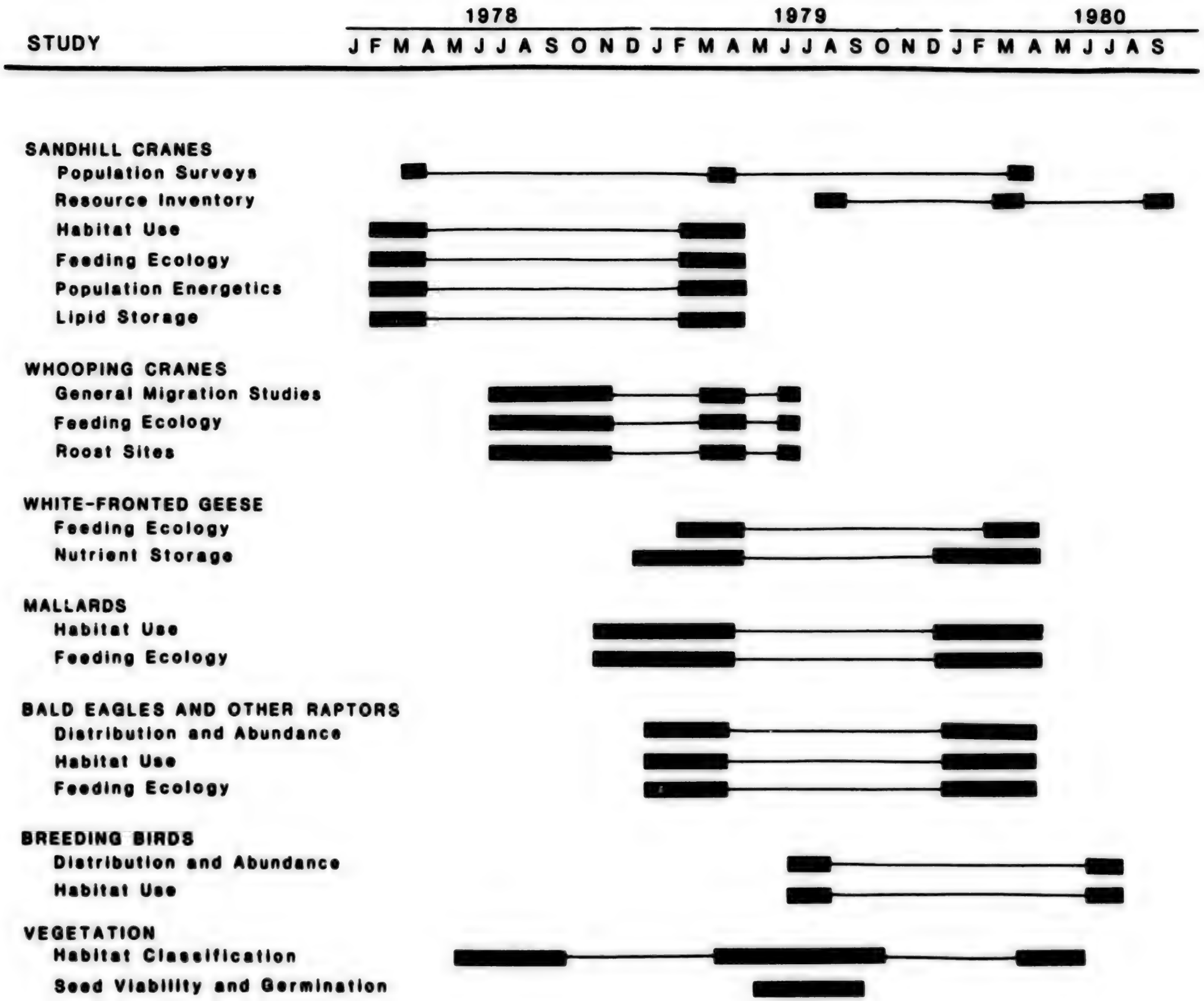

Fig. 4. Chronology and duration of various investigations under the Platte River Ecology Study (bars indicate periods of data collection).

THE STUDY AREA

Geography

The Platte River originates at the convergence of the North Platte and South Platte Rivers near the city of North Platte, Nebraska (Fig. 1). From its source, the Platte flows eastward along an S-shaped course and empties into the Missouri River near Omaha, Nebraska. Along this 500 km (310 mile) route approximately 77,210 km^2 (29,800 mi^2) are drained by the Platte and its major tributaries.

The South Platte River originates as snowmelt in central Colorado at about 3810 m (12,500 feet) above sea level (Fig. 1). From its source, the River flows southeastward, then north-northeastward, and, after crossing the Colorado-Nebraska border, flows almost due east to join the North Platte. The South Platte is about 730 km (450 miles) long and drains approximately 62,960 km^2 (24,300 mi^2).

Also beginning as snowmelt, the North Platte River flows northward from north central Colorado into central Wyoming where it gradually curls to the southeast before joining the South Platte River (Fig. 1). From its source at about 3350 m (11,000 feet) above sea level to its confluence with the South Platte, the North Platte River traverses approximately 1070 km (665 miles) and drains an area of 90,430 km^2 (34,900 mi^2).

The study area and its location in Nebraska is shown in Fig. 5. The primary focus of attention was from the town of Chapman westward to the city of North Platte, and along the North Platte River Valley from North Platte westward to the Kingsley Dam at the east end of Lake McConaughy (Fig. 5). This included 327 km (203 miles) of river valley in the Nebraska counties of Hamilton, Merrick, Adams, Hall, Kearney, Buffalo, Phelps, Gosper, Dawson, Lincoln, and Keith. The largest population centers in the study area are Grand Island, North Platte and Kearney (1980 preliminary population estimates of 33,159, 24,475, and 21,149, respectively). U.S. Interstate Highway 80 parallels the Platte River from Grand Island to North Platte.

Climate

The climate of the Platte River basin is typical of the interior of large, mid-latitude continents. The precipitation, two-thirds of which falls during the growing season, and humidity are low, summers are hot, and winters severe. Temperature and precipitation vary widely among years. Short-term weather changes are influenced by large masses of warm, moist air from the Gulf of Mexico; cold, dry air from central Canada; cool, dry air from the northern Pacific Ocean; and hot, dry air from the southwestern United States.

Mean monthly temperatures and total monthly precipitation for the duration of the study are summarized in Table 1. Mean values are comparable to those of the period 1941-70. During 1978 and 1979, however, January and February temperatures were lower than normal, and the heaviest precipitation fell earlier in the year than usual.

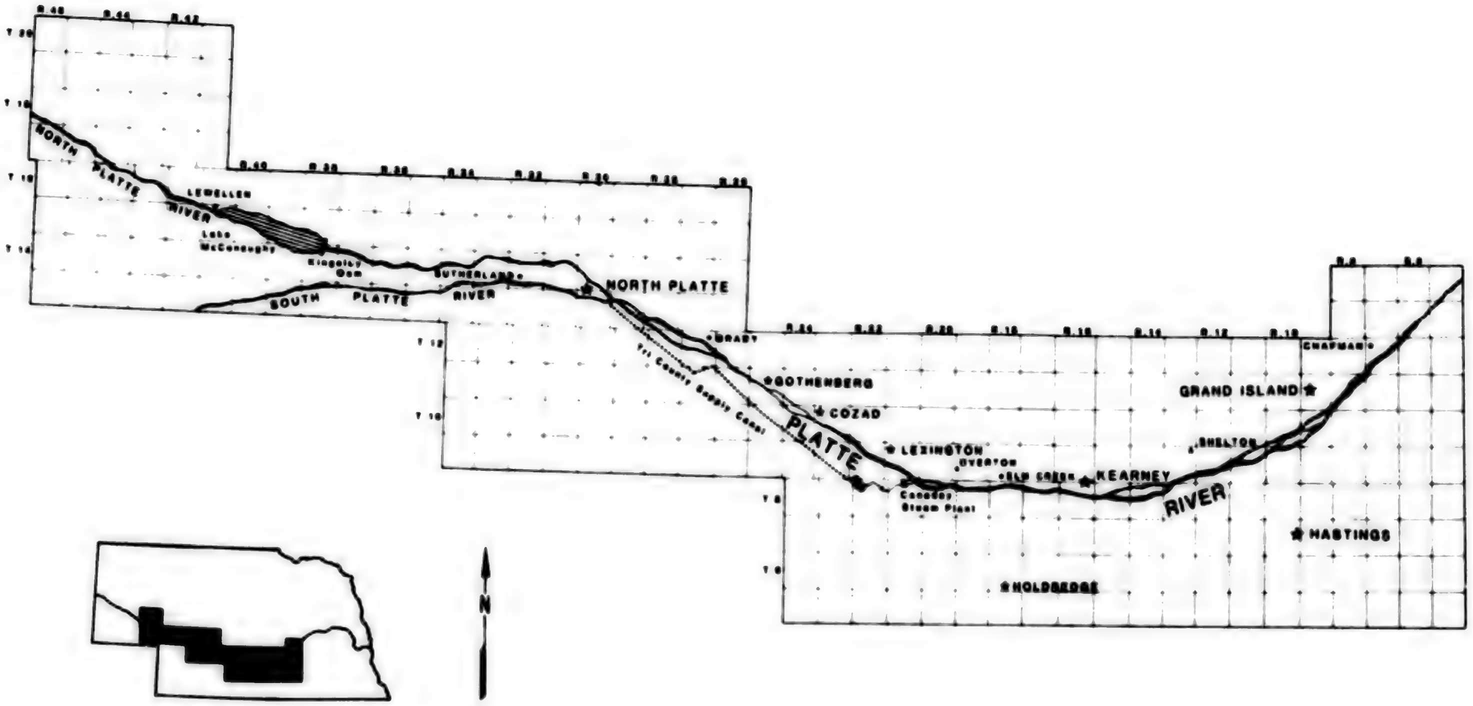

Fig. 5. The study area.

Table 1. Mean monthly temperature (°C) and precipitation (cm) on the study area (mean values from Grand Island, Kearney, and North Platte). Climatological data are from U.S. Environmental Data Service 1978-80.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature												
1978	-11.3	-9.3	1.5	10.2	14.8	21.6	24.1	22.3	19.6	10.4	1.2	-7.8
1979	-13.6	-9.0	2.7	9.2	13.9	20.7	23.3	22.9	19.7	11.8	0.4	0.9
1980	-4.9	-4.1	1.3	10.5	15.9	22.7	26.4	24.1	18.6	10.3	4.6	-0.6
Normal[a]	-5.1	-2.3	1.6	10.6	15.4	20.9	24.2	23.5	17.6	11.6	3.0	-2.8
Precipitation												
1978	0.84	3.56	1.42	13.13	9.50	2.39	7.75	6.30	2.92	1.52	3.20	2.31
1979	1.93	0.48	10.24	6.60	9.40	9.22	13.18	4.32	3.18	5.13	5.03	0.81
1980	1.57	2.03	7.11	3.56	6.55	6.55	2.62	8.89	2.29	3.00	0.23	0.18
Normal[a]	1.27	1.70	2.95	5.72	10.34	10.85	7.85	6.07	6.12	3.02	1.45	1.27

[a] Mean value from 1941-70.

Geology

The Platte River Valley, like most of western and central Nebraska, is underlain by Ogallala sedimentary rock of the Tertiary period (Bose 1977). Prior to Pleistocene glaciation (1,000,000+ years ago), easterly flowing rivers cut deep valleys across what is now Nebraska. The advance of the Nebraskan ice sheet dammed many of the rivers, causing the valleys to fill with clay, sand, and gravel; some were partially reopened by erosion during the Aftonian Interglacial period (900,000 years ago). Valleys were filled again, and river drainage patterns further altered, during and after the Kansan glacial advance (600,000-700,000 years ago). Only minor changes occurred during the ensuing glacial advances and retreats. Alluvial deposits now cover the Platte River Valley and overlie thick layers of sand and gravel that contain a major aquifer.

Vegetation

In central and western Nebraska, the Platte River Valley is characterized by forest, shrub, and sandbar vegetation on the river floodplain; lowland prairie and cultivated fields on the river terraces; and upland prairies on the loess bluffs along the ancient river escarpment. The floodplain forest, shrub, and sandbar communities have developed on coarse-textured alluvial soils adjacent to the river channel. The forest communities have open canopies and are dominated by cottonwoods with an understory of red cedar and rough-leaf dogwood. Green ash, hackberry, American elm, red mulberry, and slippery elm also occur in the floodplain forest. Adjacent to the major river channel and in areas where the forests are limited to a narrow strip along the river bank (e.g., Fort Farm Island and Mormon Island), low shrub islands and vegetated sandbars predominate. Peach-leaf willow, sandbar willow, and indigo bush are the dominant shrub species, whereas lovegrass, nutsedge, barnyard grass, cocklebur, and scattered willow and cottonwood seedlings characterize the vegetation on the low shrub islands and recently exposed sandbars.

Some lowland grasslands have been maintained for grazing and hay production but much of the native lowland prairie on the river terraces adjacent to the floodplain has been converted to cropland. The river terraces are derived from a mixture of loess and alluvial parent soil material, and frequently extend for a mile or more between the floodplain vegetation and the ancient river escarpment. Mid- to tall-grasses such as big bluestem, side-oats grama, western wheatgrass, sand dropseed, indian grass, switchgrass, and bluegrass characterize the vegetation on the lowland prairie (Hopkins 1951). Minor grasses and sedges include needle-leaf sedge, plains muhly, Canada wild rye, and small panic grass. Western snowberry, poison ivy, wild rose, black-eyed susan, American germander, fringed loosestrife, and blazing star are conspicuous forbs in the lowland prairie vegetation.

The upland prairie of the river escarpment has developed on loess-derived soils. Grasses on the upland prairies tend to be much shorter than those on the lowland prairies due to a reduction in soil moisture. Although species such as big bluestem are present in both upland and lowland prairie, their stature is much reduced on the upland sites.

Blue grama and buffalo grass are the dominant short-grass species on the upland prairie, whereas little bluestem, junegrass, western wheatgrass, sedges, downy brome, and six-week fescue are less prominent grasses (Hopkins 1951). Skeleton weed, cone flower, lead plant, scarlet gaura, and wild alfalfa are characteristic forbs of the upland prairies.

Mixed short- and mid- to tall-grass prairies develop along ravines and on slopes between the upland and lowland prairie vegetation types. These mixed prairies are composed of species found in both upland and lowland prairies and have a stature intermediate between the two types.

History

The Platte River served as a major landmark during the development of western America. The broad, flat valley provided explorers and settlers with a fertile highway through what had become known as the "Great American Desert". The river furnished drinking water; fish dwelling in the river and game that drank from it provided food; livestock grazed on the surrounding grasslands; and at eastern locations trees and shrubs supplied the wood necessary to make repairs, build shelter, and generate heat. Pioneers found that following the Platte, North Platte, and Sweetwater River Valleys took them to South Pass, a natural gateway through the Rocky Mountains. This Platte-South Pass Trail, later a part of the Oregon Trail, became a main thoroughfare to the West, supporting about 90% of all westward travel in the early and mid 1800's. The first overland mail service, the transcontinental telegraph line, the Pony Express, and the Union Pacific railroad all followed the Platte River Valley.

Government passage of the Homestead Act in 1862 encouraged the settlement of lands surrounding the Platte River Valley. The completion of railroads further fostered the development of previously uninhabited areas and provided access to eastern markets. The development of irrigation techniques in the late 1800's prompted many to see great potential in the vast expanses of land that had been too dry to be effectively cultivated.

With the 20th century came the advent of major water development programs in the Platte River Basin. In April of 1909, Pathfinder Dam in south central Wyoming was completed for the purpose of retaining over 1.2 billion m^3 (1.0 million acre-feet) of flood waters for later release to three major irrigation projects. Within the next 50 years, five additional major reservoirs were created by damming the North Platte River: Guernsey Reservoir, 1927; Alcova Reservoir, 1938; Seminoe Reservoir, 1939; Lake McConaughy, 1941; and Glendo Reservoir, 1957. By 1960 almost 8.0 billion m^3 (6.5 million acre-feet) of North Platte waters and 1.2 billion m^3 (1.0 million acre-feet) of South Platte waters were stored in reservoirs (Bentall 1975). As of 1975 nearly 1.0 million ha (2.5 million acres) of land were irrigated by waters diverted from the North Platte, South Platte, and Platte Rivers. These waters are used also to generate electricity by powering hydroelectric generators and cooling steam powered plants. Part of the water diverted for power is subsequently returned to the river.

Economy

Approximately 95% of the land in the Upper Platte sub-basin, which includes the study area, is in private ownership (Missouri River Basin Commission 1975). Agriculture accounts for 97.0% of all sub-basin lands. Of this, 57.7% is used for pasture and range. Nonirrigated and irrigated croplands represent 24.8% and 14.4%, respectively. Nearly two-thirds of the non-agricultural lands are urban developed areas. Remaining lands include privately owned irrigation and power structures, state and federal lands not cropped, canals, and any other non-agricultural lands. Less than 0.3% of all lands in the Upper Platte sub-basin are publicly-owned fish and wildlife areas.

According to the U.S. Census of Population Reports and the Nebraska Department of Labor, the number of persons employed in agriculture in counties of the study area declined by about 54% between 1940 and 1979. This decline was primarily due to technological advances which have allowed an increase of livestock and crop production although the number employed has been reduced. Employment in service-related jobs, and transportation and communication increased by 68% and 43%, respectively. Mining and construction employment increased by 148% and the number of persons working in the trades climbed 164%. The largest increases were in manufacturing (613%) and government, military, and other (721%). The overall work force in the region increased 83% during this period. The total population of the area has increased 21% from 1940-80. From 1950-78, total personal income for the region increased 123% (Source: U.S. Department of Commerce, obtained from Bureau of Business Research, University of Nebraska at Lincoln. Income data adjusted to reflect purchasing power in 1978).

SANDHILL CRANES

Introduction

Approximately 80% of the sandhill cranes in North America, including most of the midcontinent population, stop along the Platte and North Platte Rivers each spring enroute to their breeding grounds in Canada, Alaska, and the Soviet Union. In recent times, loss of river channel and meadow habitat (Frith 1974; Lewis 1977) has raised concern for the well-being of this population.

Previous studies have documented several aspects of sandhill crane biology during spring in the Platte River Valley (Wheeler and Lewis 1972; Frith 1974; Lewis 1975) but there has been a paucity of information on several key aspects important to fully understanding the role of this staging area in preparing the population for migration and reproduction. Therefore, present investigations have centered on quantitatively describing physiological changes in birds associated with the spring stopover period and monitoring nutrient storage and utilization patterns during migration and reproduction. In addition, studies have focused on defining the actual areas used by the population in the Platte and North Platte River Valleys, on obtaining refined estimates of current population size, and based on a synthesis of numerous types of information, estimating the habitat base necessary to sustain the crane population.

Distribution and Abundance

The midcontinent sandhill crane population occupies three major staging areas during its annual spring stopover along the Platte and North Platte Rivers (Fig. 6) plus a small area along the upper reaches of Lake McConaughy near Lewellen. From east to west, the three sites are designated the Kearney - Grand Island Area (staging area 1), the Overton - Elm Creek Area (staging area 2), and the Sutherland - North Platte Area (staging area 3) and encompass 578, 257, and 184 km^2 (223, 99, and 71 mi^2), respectively; an 18 km^2 (7 mi^2) area was utilized near Lewellen.

The distribution of sandhill cranes along the Platte and North Platte Rivers is restricted to a few reaches of river and the remainder of the river is uninhabited by the species (Fig. 7). Among the 406 0.8 km (0.5 mile) segments of river channel within the study area, 137 (34%) were utilized as roosts in 1979; 105 of 299 segments of the Platte River and 32 of 107 segments of the North Platte River were occupied by roosting cranes. Crane densities at 18% of the sites along the Platte River exceeded 5000 birds/segment. Highest densities occurred on staging area 1 in the channel area bordering Mormon and Shoemaker Islands. The crane density exceeded 10,000 cranes/segment at two sites.

Sandhill cranes spent the daylight hours on lands relatively close to their roosting sites on the Platte and North Platte Rivers. Photographic surveys of the Kearney - Grand Island and Overton - Elm Creek staging areas indicated that the cranes typically were distributed 1.5-3.5 km (0.9-2.2 miles) from the river channel with more than 90% of them within 4.5 km (2.8 miles). Cranes were not recorded beyond 8.3 km (5.1 miles) from the river channel. Analysis of movements of radio-marked cranes verified the patterns observed from aerial photography. The maximum

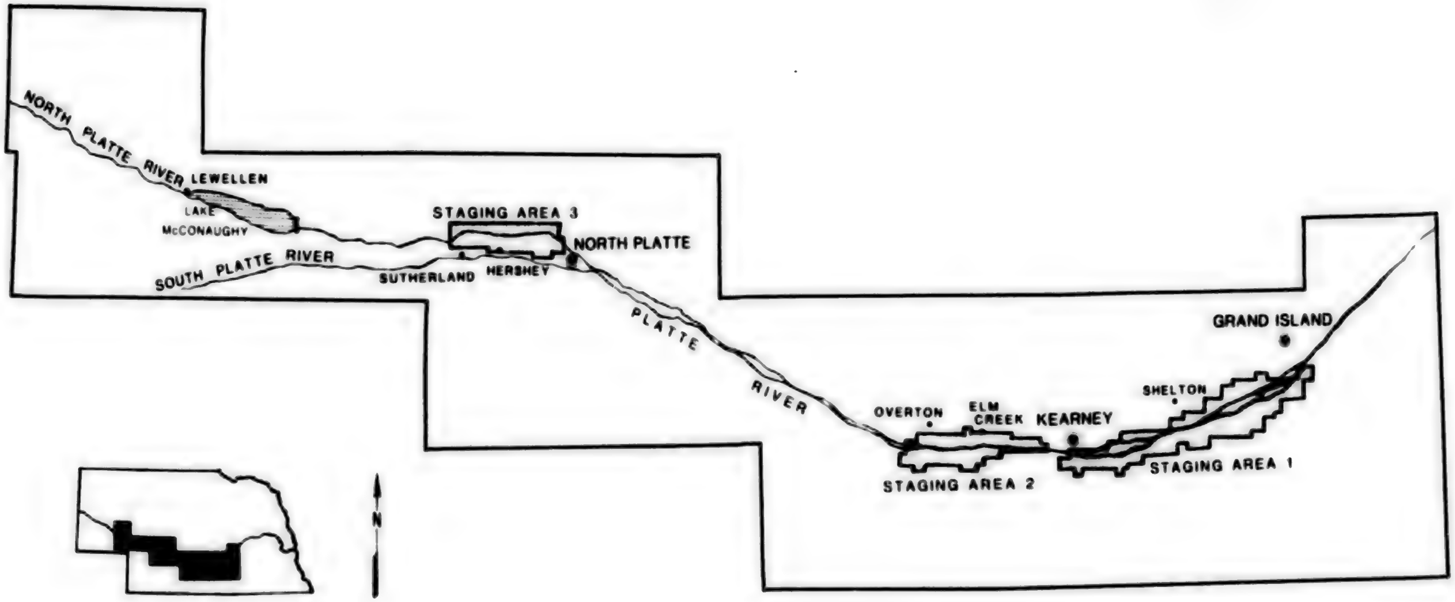

Fig. 6. Staging areas of sandhill cranes in the Platte and North Platte River Valleys.

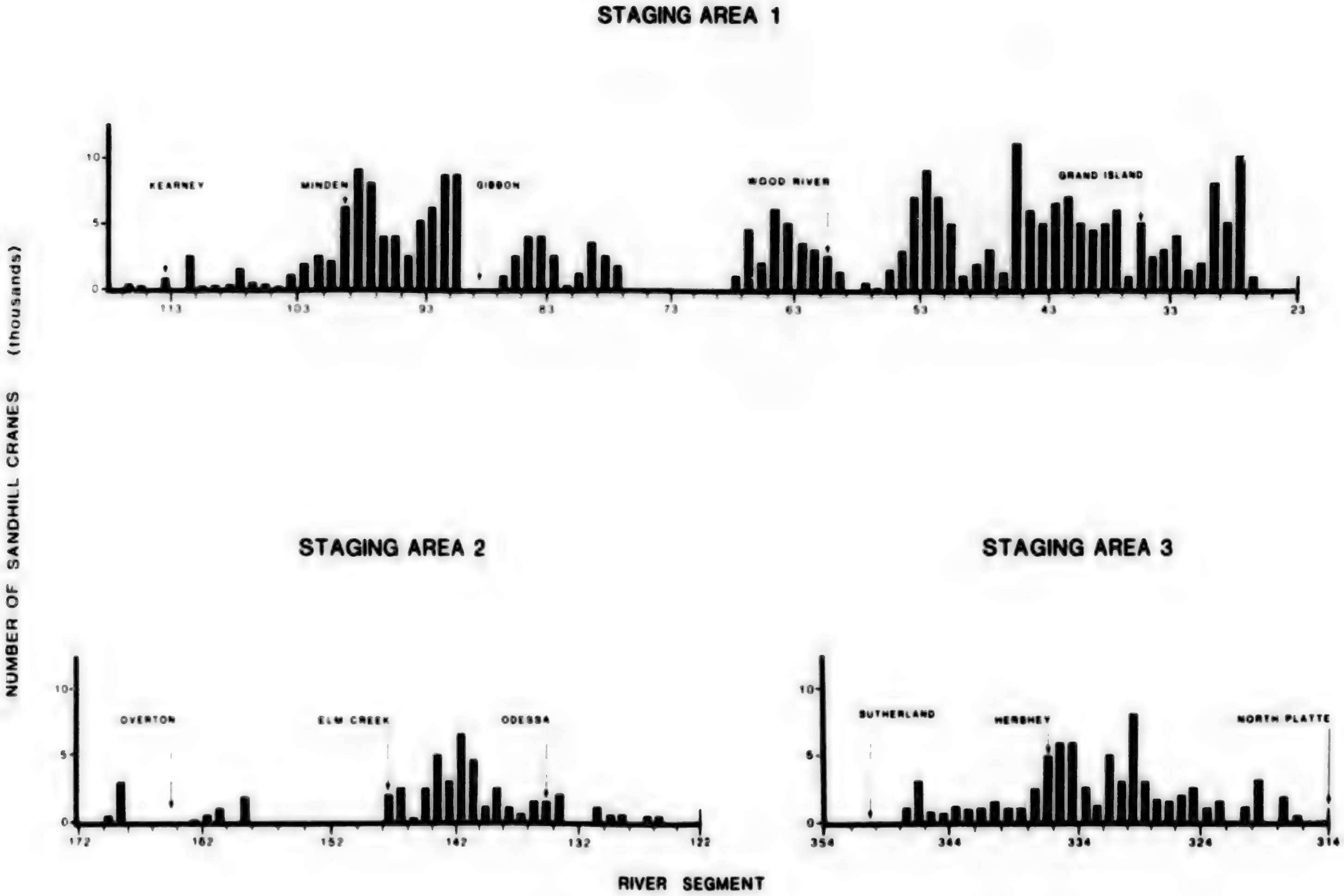

Fig. 7. Distribution of roosting sandhill cranes by 0.8 km segments of river channel.

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distance that radio-marked birds moved from the channel averaged 4.2 km (2.6 miles) during the spring staging periods in March and April 1978 and 1979. The farthest perpendicular movement from the river channel of a radio-marked bird was 5.6 km (3.5 miles).

Estimates of the maximum size of the sandhill crane population along the Platte and North Platte Rivers ranged from 306,000 to 541,000 in 1979 and 1980, respectively (Table 2). Population surveys suggest that the staging crane population reaches maximum size in early April and that the lower estimate in 1979 was partially due to the early timing of the census. Estimates for both years are based on photographic surveys and are not directly comparable with ocular estimates made during the past 23 years. Tests to evaluate the accuracy of visual aerial estimates were made during 1978 and 1979; findings suggested that observers tended to underestimate the crane population by approximately 30%. Consequently, the larger population estimate appears due primarily to recent application of more accurate censusing methodology and to later timing of the surveys rather than indicating a sizable increase in the crane population.

Approximately two-thirds of the population is located in the Kearney - Grand Island Area. Most of the remaining cranes used the Overton - Elm Creek and Sutherland - North Platte Areas (Table 2); approximately 4000 cranes occurred on the Lewellen area. Cranes occasionally stop along the Platte River during fall migration but in low numbers in comparison to spring.

Most of the sandhill cranes staging along the Platte River are of 2 races; lesser sandhill cranes occur principally west from Grand Island and individuals of the Canadian race stage principally between Kearney and Grand Island.

Staging Interval

Sandhill cranes typically inhabit the Platte River Valley from late February to early May, although most of the midcontinent population is present for only part of this period. The size of the population during March 1979, estimated visually by a team of ground observers during each of four weekly counts on all staging areas, was as follows: 5 March, 82,813; 12 March, 116,943; 20 March, 258,112; and 26 March, 245,715. These data indicate a rapid population increase until about 20 March followed by a leveling off late in the month. The small decline indicated on the 26 March count is probably due to a bias in surveys on one staging area on that date rather than an actual decline in the population. Cranes rapidly depart from the Platte Valley in April when weather conditions are favorable for migration.

Based on information collected from 20 radio-marked cranes in 1978 and 1979, sandhill cranes arriving in late February and early March remain in the North Platte and Platte River Valleys into April along with later arrivals. In 1978 and 1979, a total of 20 cranes were radio-marked and followed throughout their stay at the Platte. In 1978, six of these cranes spent a minimum of 26.2 days on staging area 1 whereas

Table 2. Estimates of peak numbers of sandhill cranes on spring staging areas in the Platte and North Platte River Valleys, Nebraska, during 1979 and 1980.

Date	Staging area			Total
	Kearney-Grand Island	Overton-Elm Creek	Sutherland-North Platte	
14 March 1979	175,473 ± 66,527	33,163 ± 22,871	51,784 ± 14,748	260,420 ± 71,933
24 March 1979	231,126 ± 67,820	22,717 ± 8,288	52,632 ± 11,702	306,475 ± 69,319
20 March 1980	179,702 ± 44,218	32,828 ± 12,163	58,714 ± 18,877	271,244 ± 49,594
24 March 1980	228,140 ± 54,092	74,106 ± 34,399	51,659 ± 70,926	353,905 ± 78,772
4 April 1980	386,063 ± 37,151	57,156 ± 36,589	--[a]	443,219 ± 67,861[b]

[a] 26 March 1980 ground count was 93,651.

[b] 1980 maximum estimate was 541,282 if 26 March ground count is used for Sutherland-North Platte staging area.

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14 cranes marked in 1979 stayed an average of 31.7 days. The difference in length of stay between the 2 years probably was due to varying weather conditions. In 1979, adverse weather conditions caused the crane population to remain along the Platte until mid-April, a delay of 7 to 10 days from the previous year.

Home Range Characteristics

A home range is defined as the total area encompassed by movements of a sandhill crane during the staging interval (Baker 1978). Home range size was estimated using a modification of the computer fill method described by Siniff and Tester (1965).

Sandhill cranes occupied relatively large home ranges during the spring staging period in the Platte River Valley. Home ranges of 20 radio-marked individuals monitored on a 272 km^2 (105 mi^2) study area near Kearney averaged approximately 36 km^2 (14 mi^2) and ranged from 12 km^2 to 67 km^2 (4.5-26 mi^2) during early spring of 1978 and 1979 (Table 3).

The cumulative home range represents the entire area utilized by a crane in meeting its needs during the spring staging period. Approximately 39% of the cumulative home range was utilized in any 5 days. Several factors probably contributed to the marked variation in home range size. The distribution of suitable roosting and foraging habitat, the degree of disturbance, and the associated need to shift activity centers are among the most significant factors influencing observed variations in home range size. Habitat characteristics of home ranges used by radio-marked sandhill cranes indicate cranes select areas containing diverse habitats including cropland, native grassland, and hayland (Table 3). Cranes occupied home ranges that averaged 44% cropland, 20% native grassland, and 10% hayland. Riverine habitat (i.e., former and present channel area) averaged approximately 18% of the home range.

Sandhill cranes exhibited a high degree of fidelity to a certain section of river channel after their arrival on the staging area. Only 2 of the 20 monitored cranes moved out of the Kearney to Shelton reach; 1 moved 18 km (11 miles) to the vicinity of Shoemaker and Mormon Island and the second bird moved westward approximately 23 km (14 miles) to the vicinity of Elm Creek. The average reach of river occupied by individual cranes was 11.8 km (7.3 miles). Cranes frequently shifted roost location from one night to the next; the average daily shift was nearly 1.6 km (1 mile).

The mean distance traveled daily by an individual radio-marked crane was approximately 9.7 km (6 miles). The cranes traveled an average of 2.8 km (1.7 miles) from their nocturnal roost site to their diurnal locations. An average of 5.4 moves was made before returning to the evening roost and each movement averaged 1.8 km (1.1 miles). Diurnal movements decreased during midday, when cranes gathered in large flocks to rest, and increased toward evening. The average distance moved per day decreased as the season progressed, implying a tendency by the cranes to occupy sites that contain the desired combination of habitat needs in close proximity.

Table 3. Home range characteristics of radio-marked sandhill cranes during spring 1978 and 1979 on study area near Kearney, Nebraska.

Crane no.	Home range size (km^2)	No. quarter sections used[a]	Home range cover types (% area)				
			Cropland	Grassland	Hayland	Riverine	Other
1-78	16	20	46.6	12.6	9.1	11.4	20.3
4-78	45	52	37.2	25.8	11.6	15.1	10.3
5-78	17	25	48.2	20.3	11.3	13.8	6.4
12-78	19	26	50.9	15.7	7.1	22.9	3.4
15-78	20	20	36.2	15.5	12.6	26.0	9.7
16-78	14	16	44.8	14.1	4.8	25.9	10.4
2-79	42	53	49.9	24.1	8.7	7.6	9.7
3-79	62	69	35.7	25.1	10.7	19.4	9.1
4-79	43	42	48.3	19.8	14.2	9.5	8.2
5-79	51	53	38.7	25.3	13.3	11.6	11.1
10-79	34	39	46.8	14.8	8.1	21.6	8.7
11-79	12	16	42.2	21.1	8.2	24.1	4.4
12-79	67	70	52.2	20.4	8.5	10.7	8.2
13-79	41	55	46.0	18.8	7.3	21.8	6.1
14-79	55	60	46.1	22.4	10.9	15.4	5.2

(continued)

Table 3. (Continued).

15-79	36	38	43.9	24.7	10.2	16.2	5.0
16-79	51	42	51.0	15.1	7.5	16.2	10.2
17-79	33	39	44.9	20.2	11.4	15.1	8.4
18-79	24	29	36.8	17.7	7.1	29.2	9.2
19-79	35	39	40.0	21.2	9.2	23.2	6.4
Average	36	40	44.3	19.7	9.6	17.8	8.5

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[a] Number of quarter sections containing locations. To estimate total home range size the areas of each used quarter section, plus certain unoccupied quarter sections, were summed. One quarter section = 65 ha (160 acres).

Habitat Use

During daylight hours, sandhill cranes in the Platte Valley occurred principally in either cropland, native grassland, or alfalfa fields (Table 4). Ninety-seven percent of 2972 diurnal radio-locations of 20 marked sandhill cranes on the Kearney - Grand Island staging area in 1978 and 1979 were in these three habitat types; more than half the locations were in cornfields, primarily grazed corn stubble. Plowed fields, winter wheat, and milo accounted for the remaining cropland use. Crane use of croplands increased from 44% during 1978 to 61% in 1979. Crane use of alfalfa dropped from 27% to 8% over the 2 years whereas use of grassland remained nearly constant. Ninety-four percent of the native grassland locations were in grazed pastures and most of the hayland usage was in mowed alfalfa fields. A typical habitat-use pattern of a radio-marked crane over the entire staging period in 1979 is shown in Fig. 8.

Crane habitat use varied with time of day and over the course of the staging period. Crane use of grasslands was high in the early morning, during midday, and just before dusk, but low in the mid-morning and early evening. Telemetry data supported previous observations of cranes utilizing large grassland tracts located within 0.8 km (0.5 mile) of the river roost sites at dawn and dusk; these sites have been termed secondary roosts by Wheeler and Lewis (1972). Cropland use was highest during mid-morning and mid- and late afternoon whereas intensity of use of alfalfa remained relatively constant throughout the day. Cranes' use of cropland increased later in the staging period and time spent in alfalfa diminished; use of grassland remained fairly constant throughout the season.

Examination of activity patterns on various habitats revealed that while on alfalfa fields, cranes spent approximately half of their time feeding; cranes fed only 39% and 36% of the time on cropland and native meadows. Cranes tend to gather on native grassland to rest during midday. Cranes on grassland spent 24% of their time resting whereas only 12% and 11% was spent in this activity on alfalfa and cropland, respectively.

Feeding Ecology

The diet of sandhill cranes varied among habitats (Fig. 9). In cornfields, cranes ate almost exclusively waste corn; ground beetles and corn borer larvae were present in some samples but only in trace amounts. In contrast, cranes foraging in alfalfa fields and grasslands consumed primarily invertebrates. The proportions of animal food eaten by cranes in grasslands, alfalfa fields, and cornfields were 99%, 82%, and <0.5%, respectively.

Cranes obtained the bulk of their total diet from cornfields. The average dry weights of food samples from cranes collected while feeding in cornfields in 1978 and 1979 were 27 and 19 g; samples from cranes feeding in alfalfa fields and grasslands averaged less than 1 g during each year.

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Table 4. Diurnal habitat use by radio-marked sandhill cranes in the Platte River Valley during 1978 and 1979.

Year	No. of cranes tracked	No. of locations	Home range cover types (% time)			
			Cropland	Grassland	Hayland	Other
1978	6	1108	44	28	27	1
1979	14	1864	61	27	8	4
Combined	20	2972	55	27	15	3

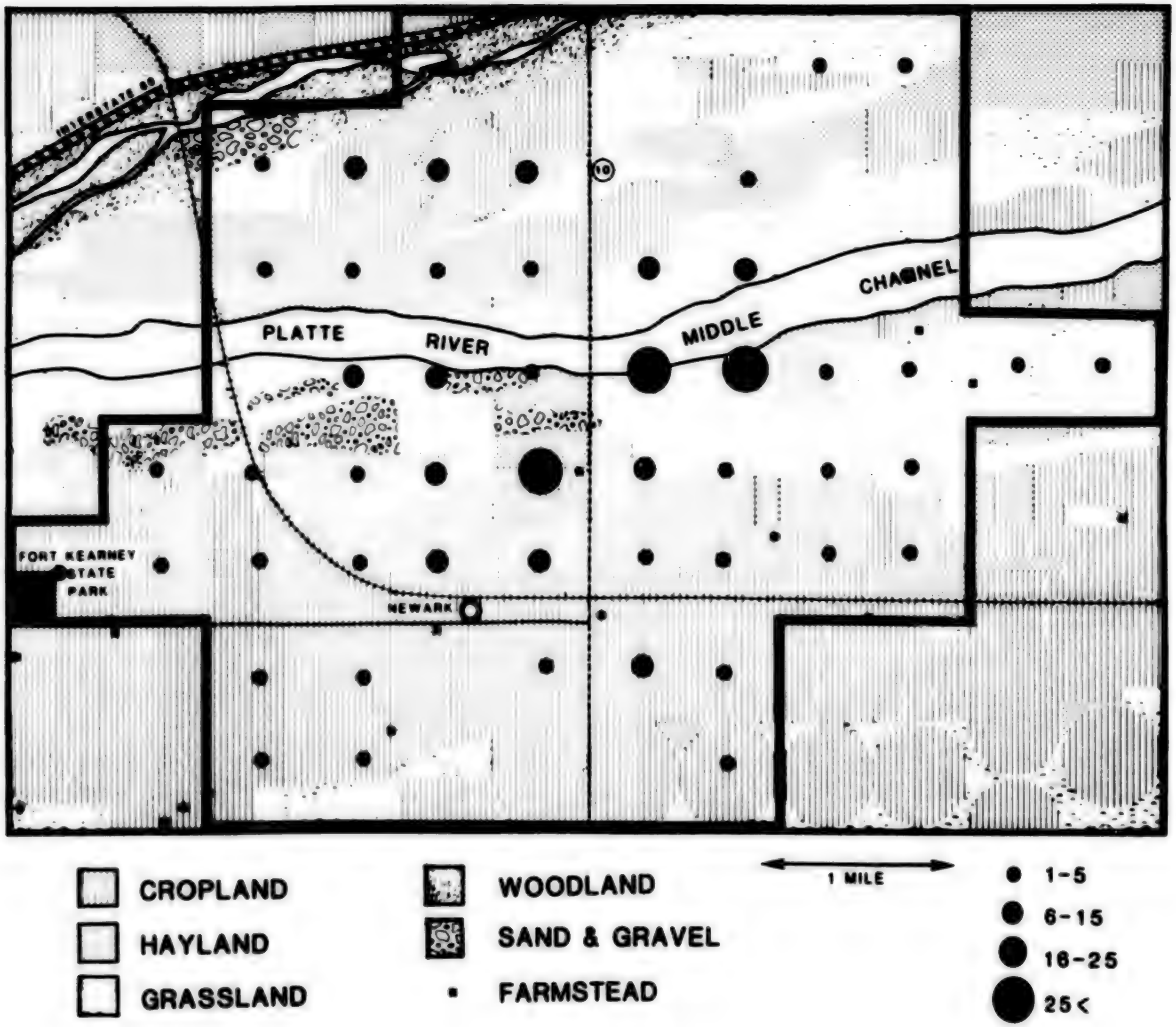

Fig. 8. Home range characteristics of a radio-marked sandhill crane in the Platte River Valley during spring 1979. Home range boundaries are shown in color; habitat-use patterns are identified by size and location of closed circles (each circle represents number of sightings in one quarter section).

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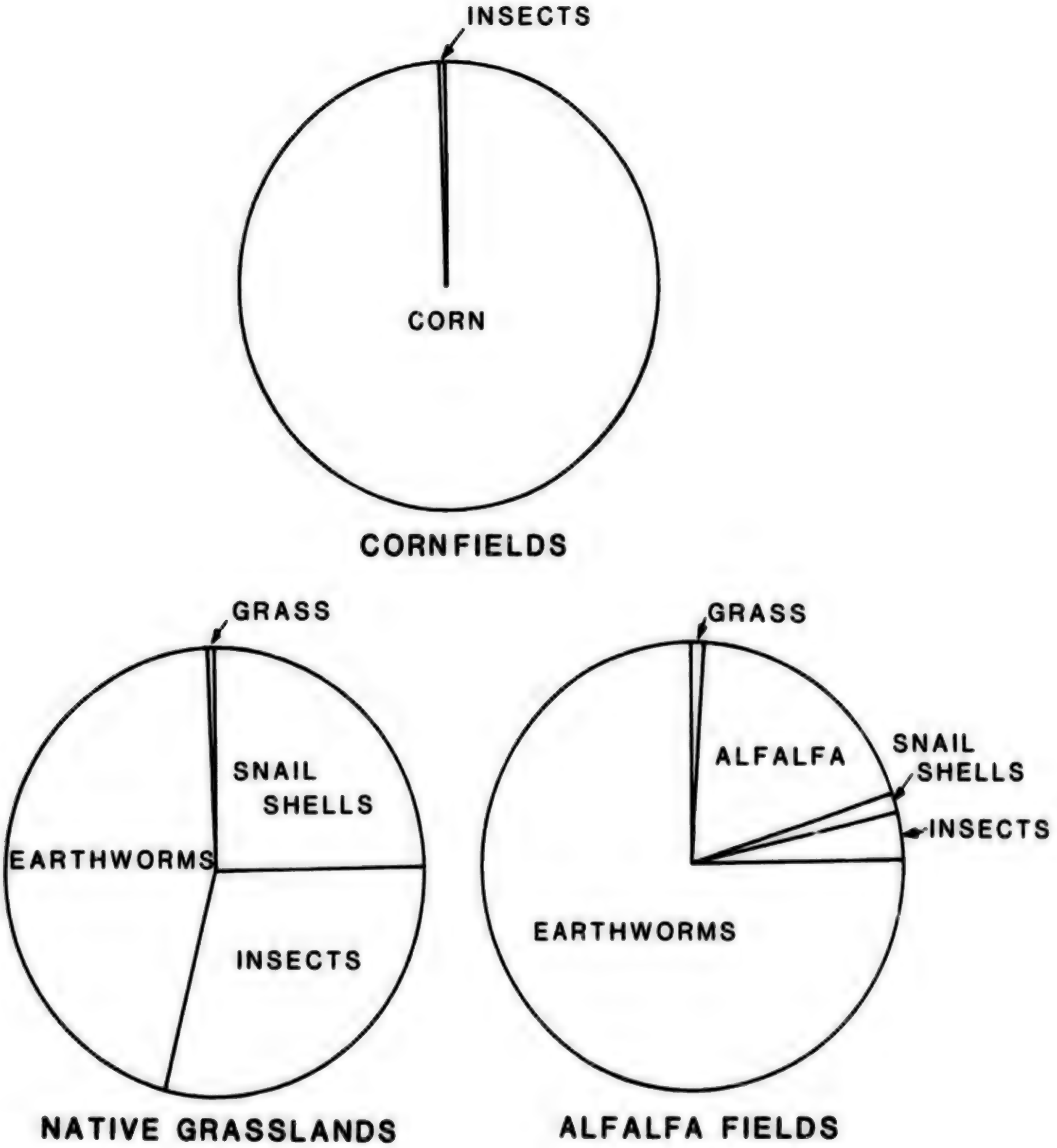

Fig. 9. Principal foods of sandhill cranes during spring on the major foraging habitats.

The cranes feeding in cornfields ate principally waste corn, whereas the birds foraging in grasslands consumed earthworms, snails, crickets, grasshoppers, sowbugs, spiders, and adult and larval beetles. The only plant foods consumed in grasslands were grass leaves. Earthworms were the predominant animal food item on alfalfa fields, and alfalfa leaves and stems were the primary plant foods.

Cornfields provide cranes with large quantities of readily digested food of high energy content whereas the grasslands and alfalfa fields are better sources of protein and minerals, in particular calcium. Time-activity and telemetry data were integrated with food habits information to develop a better understanding of the effects of nutritional requirements on crane feeding behavior. These analyses indicate that cranes feeding in cornfields gained energy at 10-20 times the rate of expenditure. On grasslands and alfalfa, however, the cranes used more energy than was ingested and thus temporarily functioned at a net energy loss in order to increase the protein and mineral content of their diet. Therefore, cranes sacrificed time and energy to satisfy nutrient requirements.

Three other lines of evidence suggest cranes cannot obtain all their mineral requirements from corn. First, corn contains very low levels of calcium, i.e., 0.02% (Morrison 1957). Second, more than half of the birds collected from grassland habitats had ingested snail shells which contain 30-40% calcium. Third, some cranes regularly visited a pasture 8 km (5 miles) southeast of Grand Island to eat lime concretions which they dug from the prairie sod with their bills. Five of the cranes which were collected on the staging area during the spring of 1979 had ingested one or more of these lime concretions. The foods from grasslands and alfalfa fields increased the calcium intake by more than 500%. Cranes cannot feed enough hours in cornfields to obtained an equivalent amount of calcium.

Crane foraging patterns are influenced by the diverse nutritional needs satisfied by foods available from different habitats. Analyses of the composite daily diet of cranes indicated that 96% of their food, by dry weight, was obtained from cornfields and 4% from alfalfa fields and grasslands. The 4% of the diet obtained from grasslands and alfalfa fields increased the protein content of the composite diet by 10-20%. The cranes could have obtained an equivalent quantity of protein by increasing their foraging time in cornfields by 10-20%, and avoided the other habitats. However, corn is deficient in certain amino acids, particularly tryptophan and lysine, whereas invertebrate foods contain markedly higher levels. The utilization of grasslands and alfalfa fields for foraging, therefore, suggests that protein quality is an important consideration.

Fat Storage and Utilization

Sandhill cranes deposit substantial fat reserves during stopover periods on their annual spring migration across the Great Plains. The fat content in carcasses of adult lesser sandhill cranes increased from approximately 8% of body weight at departure from wintering grounds in west Texas in mid-February to 23% at departure from staging grounds in central Saskatchewan in late April. Carcasses of adult cranes departing for the breeding grounds from the Last Mountain Lake area of central Saskatchewan in late April and early May contained an average of approximately 900 and 800 g of fat in males and females, respectively.

The Platte River Valley serves as a major conditioning area during spring migration. Adult male and female cranes deposited fat at a daily rate of 13.2 and 9.1 g, respectively (Fig. 10). Assuming a 30-day stopover interval, adult males and females deposited approximately 400 and 275 g, respectively, or 44% and 34% of the total fat reserve acquired on staging areas in the Great Plains Region. The actual magnitude of fat stored by individuals during their stay at the Platte varies directly with the duration of time spent there.

Although the pace of migration varies among years, as cranes adjust to existing weather conditions in the northern Great Plains during April, fat deposition is not slowed by a delayed departure from the Platte Valley. For example, during 1979 most of the cranes remained about a week longer at the Platte than during the previous year and fat deposition continued at a pace similar to the previous month. These data suggest that food resources were ample to allow the cranes to delay their departure date without adversely affecting physical condition and deposition of fat reserves.

When leaving staging areas in the Platte Valley, sandhill cranes migrate northward across the Dakotas but seldom stop for prolonged periods until reaching central and western Saskatchewan and eastern Alberta. The cranes remain in central Canada until early May. The birds are more dispersed on these staging areas than they are along the Platte and wheat replaces corn as the principal energy source. There appears to be limited utilization of fat reserves during the movement from Nebraska to central Saskatchewan because of ample food resources and the slow pace of migration across the plains. However, a substantial part of the fat reserve is utilized after departure from central Saskatchewan and before arrival on the breeding grounds. Based on carcass analyses of cranes collected both at departure from Saskatchewan and arrival on the breeding grounds in Alaska, an estimated 40% of the fat reserve acquired on staging areas in the Great Plains is expended before arrival on breeding grounds in the Yukon-Kuskokwim Delta of western Alaska.

The fat reserves of adult females upon arrival at the breeding grounds averaged approximately 480 g. These reserves were largely utilized during the nesting period (Fig. 10) and were expended at a rate of approximately 6.7 g/day. Cranes were observed feeding during the prelaying and laying periods. Time budget observations indicated that cranes spent 30% and 20% of each day feeding during the prelaying and laying phases, respectively. The presence of substantial fat reserves allows the female to search for foods containing high quality protein needed for egg formation although such a feeding strategy may be inefficient energetically. Males did not undergo a similar decline in fat content during the nesting period.

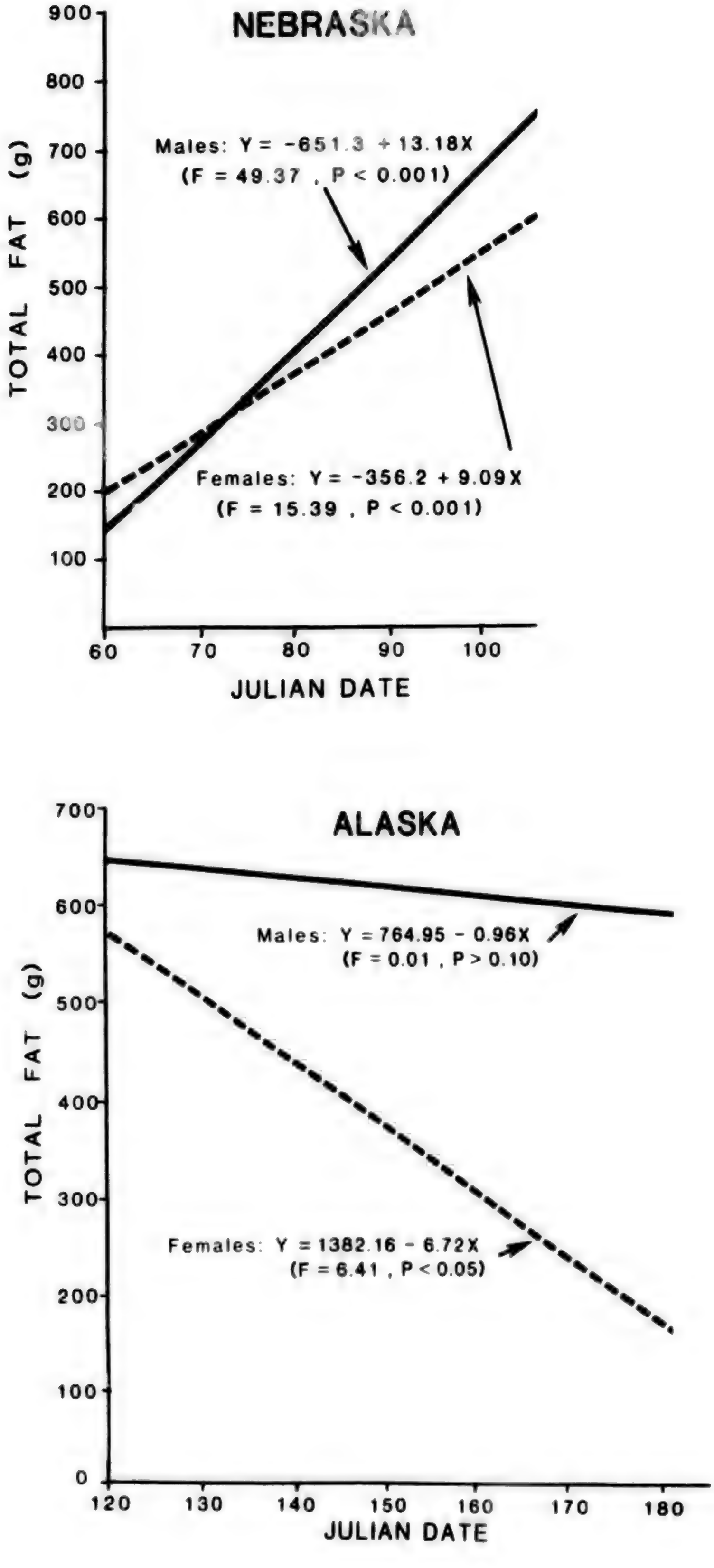

Fig. 10. Daily rates of fat deposition by adult male and female sandhill cranes during the spring staging period in Nebraska and utilization patterns during the nesting season in Alaska.

Population Energy and Food Requirements

Modelling food and energy requirements

The food and energy requirements of the crane population were estimated with a mathematical model of the relationships shown in Fig. 11. First, the existence energy requirements of individual cranes were calculated with an equation from Kendeigh et al. (1977:143):

$$M = 4.235\ W^{0.5316}$$

where M = existence metabolism in kcal/bird/day, and W = body weight in grams. Crane body weights were estimated from data collected in the Platte River Valley. Only a few juveniles were examined, consequently we could not determine their weight trends in Nebraska; juvenile male and female lesser and Canadian sandhill cranes were, therefore, assigned mean body weights of 3313, 2807, 4353, and 3640 g, respectively, based upon data from collections in Nebraska. Adult male and female lesser sandhill cranes weighed approximately 3051 and 2927 g on 1 March and gained 25.0 and 13.6 g body weight/day while in Nebraska. Adult male and female Canadian sandhill cranes weighed 3972 and 3728 g and gained 22.1 and 13.1 g/day. The energy increments required for weight gains (9.38 kcal/g) and activity (+10%) were taken from Kendeigh et al. (1977:152, 178). Finally, the energy requirements of individual cranes were converted to food requirements assuming that each gram of corn provided 4.0 kcal of metabolizable energy (Sibbald 1979).

The daily corn requirements of the population were calculated from the individual energy requirements, and estimates of population size and composition (Fig. 11). Daily population size was assumed to increase slowly from 1 March to a peak on 31 March according to the equation:

$$\text{Daily population} = \text{Maximum population}/[1+e^{-0.35(\text{Date}-15.5)}]$$

where maximum population can be varied as desired, and date increases from 1 to 31. The daily population then decreases rapidly from 1 to 15 April according to the equation:

$$\text{Daily population} = \text{Maximum population} - \text{Maximum population}/[1+e^{-0.75(\text{Date}-7.5)}]$$

where date increases from 1 to 15. Based on the crane census data (cf. Table 2), 69%, 13%, and 18% of the birds were assigned to staging areas 1, 2, and 3, respectively. Measurements of the cranes collected during the feeding ecology research suggest that approximately 50%, 95%, and 100% of the populations in staging areas 1, 2, and 3 are lesser sandhill cranes. Juveniles constitute 11.6% of the population in the model (Buller 1979), and juvenile and adult sex ratios are 50:50 and 55:45 males:females (cf. Lewis 1974:33-34).

Food requirements and availability

The predicted daily corn requirements of individual cranes varied from a low of 0.08 kg/bird for immature female lesser sandhill cranes to

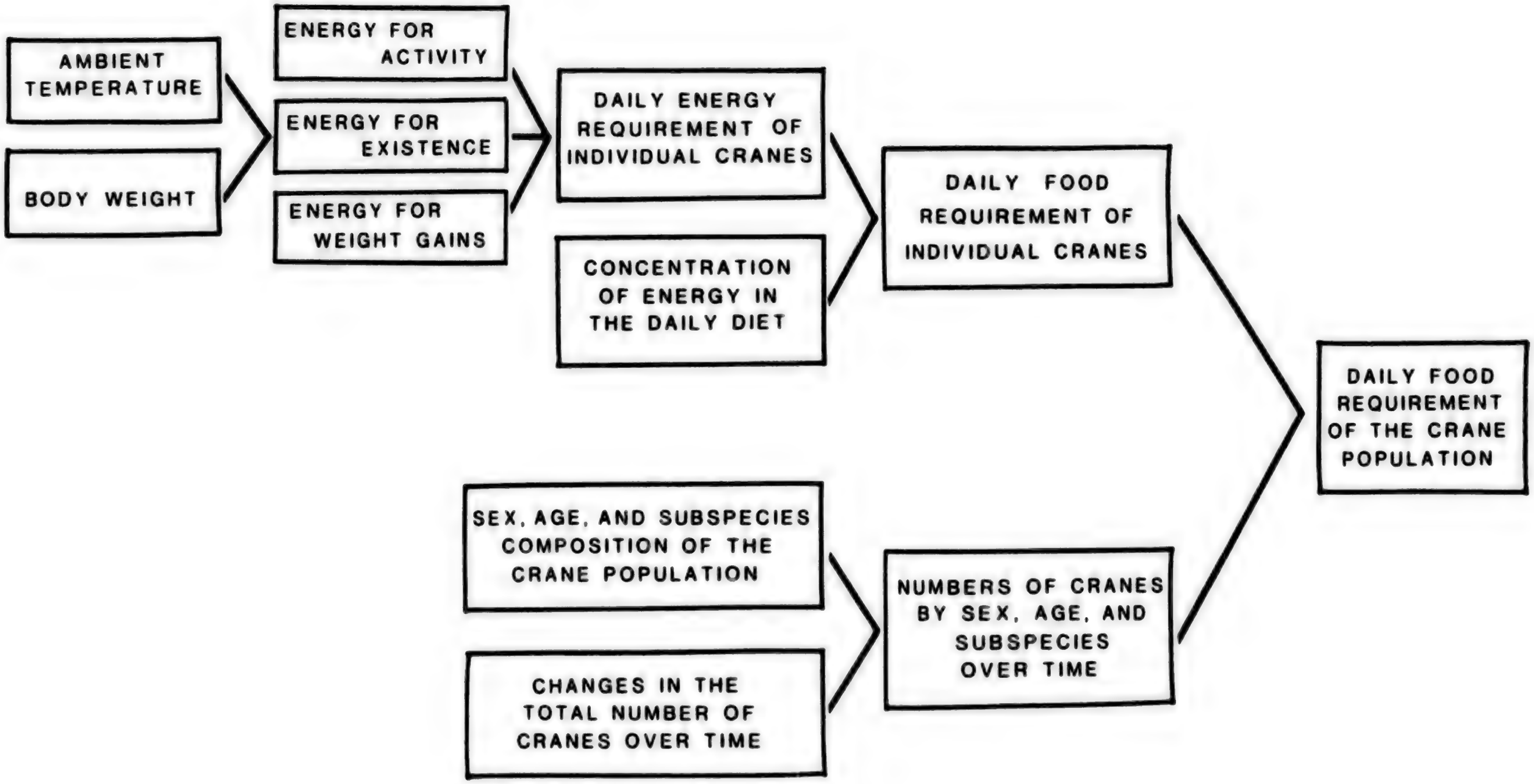
AMBIENT TEMPERATURE
BODY WEIGHT
ENERGY FOR ACTIVITY
ENERGY FOR EXISTENCE
ENERGY FOR WEIGHT GAINS
DAILY ENERGY REQUIREMENT OF INDIVIDUAL CRANES
CONCENTRATION OF ENERGY IN THE DAILY DIET
DAILY FOOD REQUIREMENT OF INDIVIDUAL CRANES
SEX, AGE, AND SUBSPECIES COMPOSITION OF THE CRANE POPULATION
CHANGES IN THE TOTAL NUMBER OF CRANES OVER TIME
NUMBERS OF CRANES BY SEX, AGE, AND SUBSPECIES OVER TIME
DAILY FOOD REQUIREMENT OF THE CRANE POPULATION

Fig. 11. Conceptual model of sandhill crane population energy budget during the spring staging period in Nebraska.

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a high of 0.15 kg/bird for adult males of the Canadian race. The daily corn requirements for hypothetical maximum populations of 350,000 and 450,000 cranes (Fig. 12) increased from 0.3 metric tons (1 metric ton of corn = 10^3 kg ≃ 40 bushels) on 1 March to 44.6 and 57.3 metric tons, respectively, on 31 March. The cumulative requirements for populations of 350,000 and 450,000 cranes were 1023 and 1315 metric tons of corn, including 711 and 914, 131 and 169, and 181 and 232 metric tons for staging areas 1, 2, and 3.

The availability of waste corn in the Platte River Valley was sampled on randomly-selected cornfields at the time of harvest, before crane arrival, and after crane departure (Table 5). On each field, all the corn on ears was collected from three random 40.5-m^2 quadrats, and all the individual kernels from three 4.05-m^2 quadrats within the larger plots. The mean density of waste corn on the fields following fall harvest was nearly 400 kg/ha (Table 5). Interviews with farm owners and managers indicated that yields on the same fields averaged 6214 kg/ha (≃ 101 bushels/acre) for a 6-7% rate of loss during harvest operations. The acreage of corn harvested within the study area was taken from our analysis of the habitat characteristics of staging areas.

Statistically significant changes in total waste corn availability occurred between fall harvest and crane arrival, and between crane arrival and departure (Table 5). Nearly half of the available corn was removed during winter when 26 of the 30 fields sampled were grazed by livestock. Changes in corn availability during winter were probably due to livestock feeding because the loss was primarily of ear corn; kernel corn losses were not statistically significant ($P>0.05$). Conversely, changes in corn availability that occurred during the crane staging period were kernel corn losses; there was no significant decrease in ear corn at that time.

Waste corn availability at the time of crane arrival was 205 kg/ha, and at the time of departure 128 kg/ha (Table 5). Data from the study of mallard winter ecology indicate that 0-25% of the fields in the study area are tilled in the fall. This level of fall tillage would leave a total weight of waste corn present at crane arrival of between 6529 and 8424 metric tons, and at crane departure, between 4077 and 5260 metric tons. The loss of corn during the staging period was, therefore, between 2452 and 3164 metric tons. Using the estimates of population food requirements (1023-1315 metric tons), the cranes accounted for nearly half of the total corn use. Among the other factors affecting corn availability would be continued livestock feeding, and use by ducks, geese, and other wildlife. The data and analyses indicate the cranes used only 10-20% of the corn available at arrival, and left behind a quantity equal to 3-5 times their total requirement.

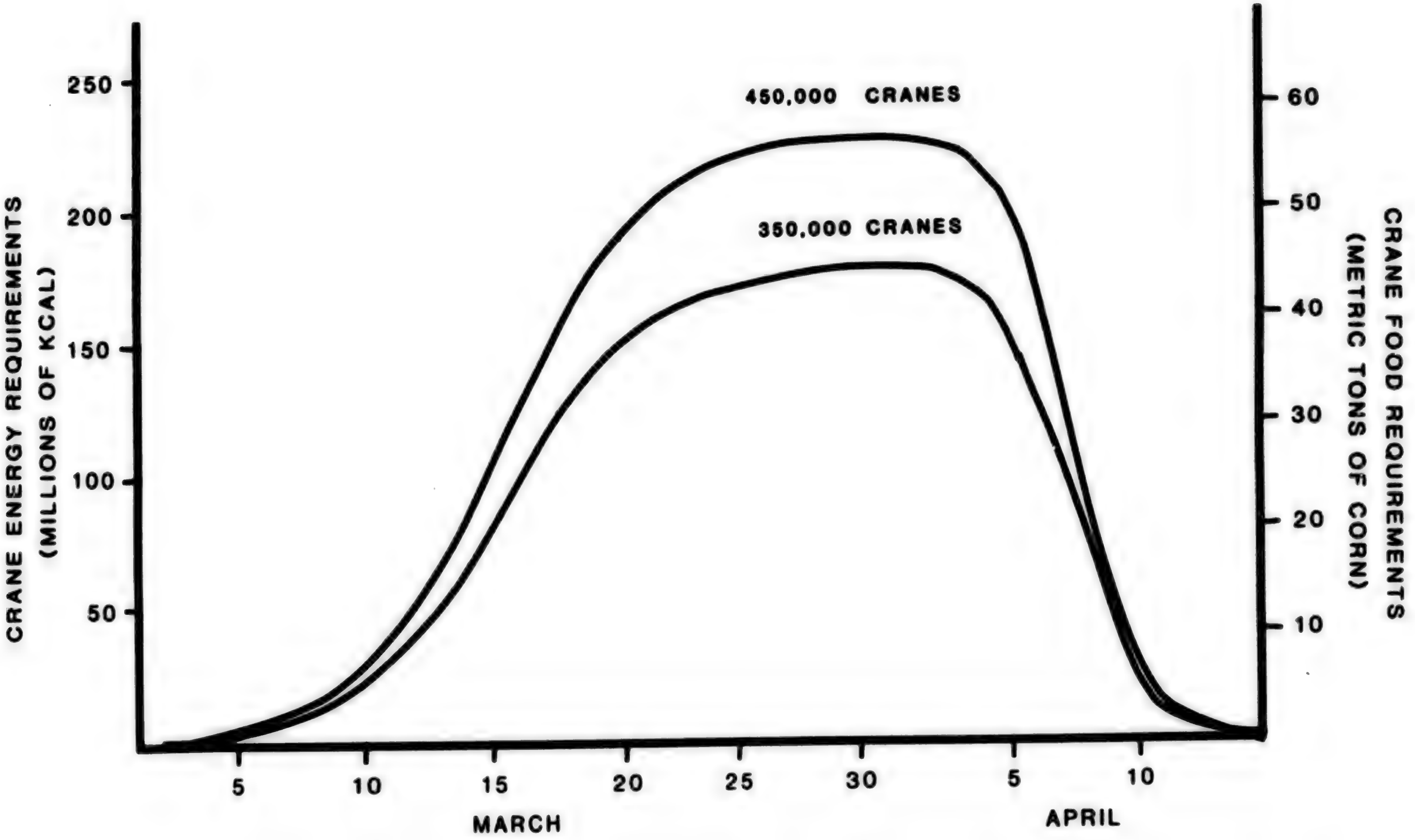

Fig. 12. Estimated energy and food requirements of the sandhill crane population during the spring stopover period at projected population levels of 350,000 and 450,000 individuals.

Table 5. Changes in the availability of waste corn (kg dry wt/ha) on the Platte River study area.

Type of corn sampled	Time of sample collection After corn harvest (early November 1978) n = 30 fields	P^a	Before crane arrival (early March 1979) n = 29 fields	P	After crane departure (early April 1979) n = 25 fields
Kernel	100	NS	85	*	38
Ear	299	*	120	NS	90
Total	399	*	205	*	128

[a] P = significance level of t-test between means in adjacent columns. * = $P<0.05$; NS indicates $P>0.05$.

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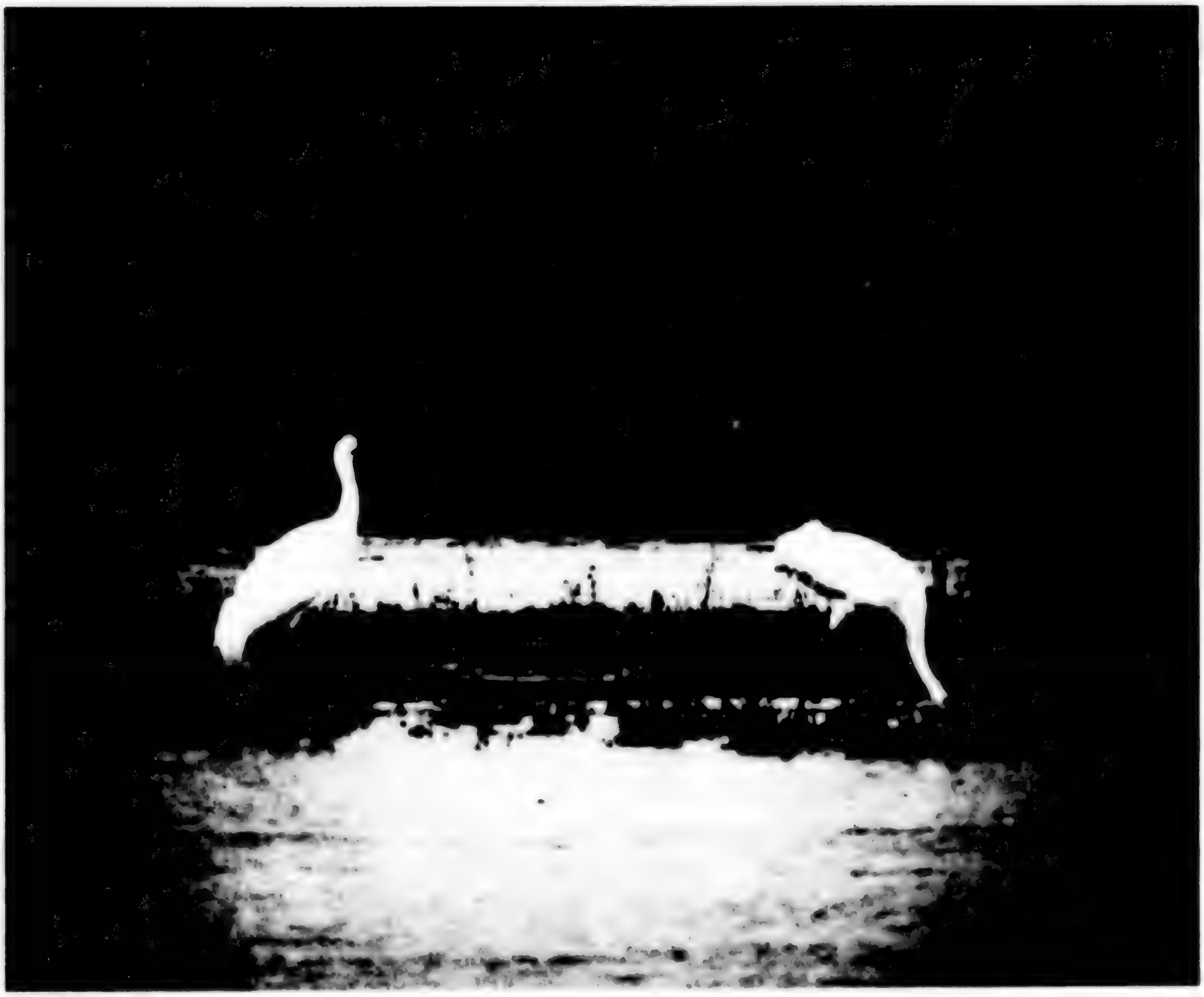
WHOOPING CRANES



Historical Perspective

Past history

Whooping cranes presumably were common in Nebraska early in the 19th century. In 1820, Thomas Say observed that "great flights of geese, swans, ducks, brant and cranes have been passing up the (Missouri) river" arriving 19 March opposite Engineer Cantonment (Fort Calhoun, Washington County, Nebraska) (Allen 1952). Swenk (1933) suggested that "the cranes" noted by Say must have been whoopers although the date listed is almost 2 weeks before the normal start of the whooping crane migration. Allen (1952), however, thought that the "great flights ... of cranes" were chiefly sandhill cranes, with perhaps an occasional whooper present. The first reports of whooping cranes in the Platte River Valley came following the establishment of the Oregon Trail in 1841, the Mormon Trail in 1847, and the arrival of significant numbers of settlers.

The first detailed list of whooping crane sightings in Nebraska was published in the early 1930's (Swenk 1933). A total of 93 sightings from Nebraska, involving 998 migrant cranes (1912-33), was documented in this publication. Only 45 sightings involving 147 whooping cranes were made outside of Nebraska during this period. Most of the Nebraska sightings were in the Big Bend region of the Platte River Valley.

Swenk (1933) was the first to indicate the importance of the Platte River to migratory whooping cranes and based his conclusions on four factors: (1) the large number of sightings from the Big Bend, (2) the scarcity of sightings from other areas, (3) discussions with old-time hunters who spoke of large flocks of whooping cranes visiting the Platte in spring, and (4) Swenk's belief that the cranes made a mid-migration stop to feed and rest in the Platte region. His findings, however, were based solely on the fragmentary data obtained from the literature.

Sightings during 1934-44 were compiled by Brooking (1934, 1943a, 1943b, 1944) and were published as lists of observations and a report on the status of the species.

Knowledge of whooping crane habits expanded markedly in the early 1950's with publication of a monograph by Allen (1952). He re-assessed the sightings reported by Swenk and Brooking and developed a list which he felt represented valid sightings in Nebraska for the period 1820-1948. In the monograph, many of the sightings reported by Swenk and Brooking were eliminated. The final list totaled 123 sightings of which 87 occurred in counties bordering the Platte River. Allen also believed the Platte was a major stopping area for whooping cranes on the basis of the same criteria described earlier but there still remained a rather fragmentary picture of the crane's overall distribution during migration.

Recent history

Whooping crane use of the Platte River apparently has declined markedly in recent decades. Confirmed sightings of these birds on or near the Platte River during 1912-49 are provided in Appendix C. During the past 30 years (1950 - spring 1980) there have been only five confirmed sightings of whooping cranes on or near the Platte River. The sightings have been made from Overton eastward to Chapman, and four have been within the areas designated as critical habitat for the species (Federal Register 15 May 1978) (Fig. 13). Three of the sightings have been in spring (17-18 April 1980; 19 April 1980; 4 May 1950) and two in the fall (21-22 October 1966; 31 October - 1 November 1974).

Information regarding the habitat use and behavior of the cranes exists for four of the sightings. The five birds observed northeast of Phillips on 21-22 October 1966 were first seen loafing on sandbars in the middle of the Platte just upstream from the Chapman Bridge on 21 October. These birds roosted overnight in the same area. At 0730 on 22 October the cranes were seen on a wheat field about 5 miles southwest of their river roost site. The birds flew back to the river for a brief time and then departed at about 1100 to continue their migration. They were tracked by automobile to the vicinity of Red Cloud, Nebraska approximately 100 km to the south of the Platte River.

The two adults observed 3.2 km (2 miles) east of the Minden Interstate Highway 80 interchange on 31 October - 1 November 1974 used the Platte for loafing, feeding, and roosting. These birds loafed on the sandbars in the middle of the river and probed in adjacent shallow waters. Movements of approximately 0.8 km (0.5 mile) upstream and downstream from the roost site were observed and on at least one occasion the cranes were observed feeding in a cornfield on the south side of the river.

The pair seen on 17-18 April 1980 were also located just east of the Minden I-80 interchange. They were first observed at 0645 feeding in a recently disced cornfield 3.2-4.8 km (2-3 miles) from the river. Feeding continued until 0815, when the cranes flew to the Platte River and loafed there for about 25 minutes. The birds left the river at 0845 and were seen at 0930 in a plowed cornfield 1 mile south of the river. Observations ended after a few minutes because the birds left the area. When relocated at 1030, the cranes were foraging in a recently burned pasture on the Lillian Annette Rowe Sanctuary of the National Audubon Society. Although foods taken by the whooping cranes were not identified, sandhill cranes collected while foraging in similar habitat in the same general area were feeding on earthworms. The whooping cranes left at 1100 and were not observed until 0820 the following morning, at another location on the Platte River. Observers suspected that the birds had roosted in that spot overnight. These cranes were observed loafing, preening, dancing, and probing in the shallow water. The cranes left the river at 0845 and were not seen again.

Seven whooping cranes seen flying with sandhill cranes along the Platte River south of Kearney on 19 April 1980 were not observed on the river itself. Little information is available for the 4 May 1950 sighting of one crane near the Platte River at Overton; it is not known if the bird actually used the river.

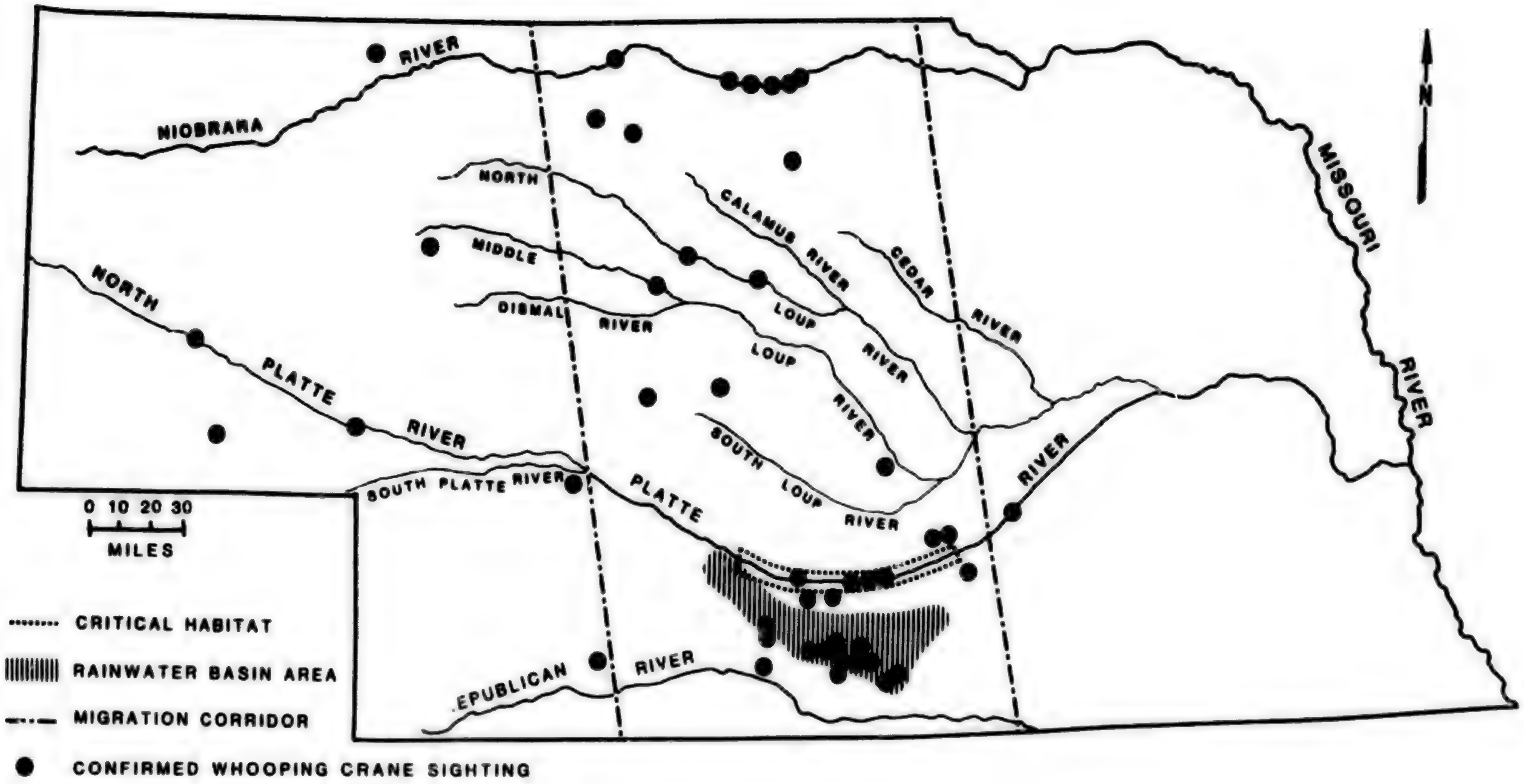


Fig. 13. Migration corridor and confirmed sightings (1950 - spring 1980) of whooping crane in Nebraska.

Characteristics of the Platte River at each location known to have been used by whooping cranes are presented in Appendix D. Although the sample size is small, it is apparent that the birds prefer to roost in a wide river channel which has low, exposed, bare sandbars, relatively shallow water, slow rates of flow, and isolation from human disturbance. Feeding sites are usually within 4.8 km (3 miles) of the river. Habitat requirements are described in more detail in following sections.

Migration Corridor

It is possible to delineate the primary migration corridor of whooping cranes through Nebraska by plotting all of the confirmed sightings in the State during the last 30 years and drawing straight lines to enclose from 70-100% of them at each latitude (see Bellrose 1972). The resultant corridor through Nebraska is 160-192 km (100-120 miles) wide and angles 15° west of north (Fig. 14). The eastern edge of the corridor intersects the northern border of the state at 98°45' longitude and the southern border at 98°15' longitude. The western edge intersects the northern border at 101°00' longitude and the southern border at 100°30' longitude. Eighty-two percent of all confirmed, post-1949 sightings in Nebraska occur within the corridor; the remaining sightings are primarily to the west. Significant physiographic features within the corridor include the Niobrara River from 40 km (25 miles) west of Valentine to its confluence with the Keya Paha River; a portion of the sandhills; a substantial portion of the Calamus, North Loup, Middle Loup, and South Loup Rivers; a stretch of the Platte River from North Platte to Grand Island; the Rainwater Basin Area south of Kearney; and part of the Republican River.

Chronology of Migration

The chronology of spring and fall migration through Nebraska was well documented by Allen (1952); data from the past 29 years (1950-79) have shown a similar pattern.

Spring migration proceeds quite rapidly. Extreme dates for confirmed sightings are 10 March and 15 May; most cranes have been observed between 1 April and 20 April. In the past 29 years whooping cranes have been seen in Nebraska from 3 April through 4 May. Juveniles returning north with their parents have been seen from 14-19 April.

During fall migration, most are seen from 10 October through 1 November, with extreme dates of 22 September and 14 November. In the last 29 years, cranes have been observed in Nebraska from 3 October - 10 November. The first migrants to reach the state each fall are usually individuals or pairs without young. Family groups begin arriving around 16 October, and numbers of sightings peak from 22-27 October. Families have been seen in the state as late as 10 November.

Feeding Ecology

Whooping cranes forage in a variety of habitats. Fourteen upland and 10 wetland habitat types were represented among 120 feeding sites investigated along the migration route in the Great Plains (Table 6). Eighty-four percent of the sites were in upland habitats, and 80% of those involved agricultural lands. Fields containing emerging small grains or small grain stubble were the predominant agricultural habitats utilized. The use of wetland habitats for foraging was generally associated with sites in the vicinity of evening roosts.

Feeding sites in upland habitats were characterized by excellent horizontal visibility (usually an unobstructed view for at least 91 m (100 yards) in all directions and often an unobstructed view for several hundred meters in all directions), a lack of tall trees and dense shrubs immediately around the site, short vegetation on the site (often less than 30 cm high), little topographic relief (usually less than 9-12 m (30-40 feet) of relief, often less than 1.5-3.0 m (5-10 ft)), and gradual slopes (usually less than 7-9° of slope, often less than 4-5°). Feeding sites in wetland habitats were usually characterized by water less than 0.4-0.6 m (1.5-2.0 feet) deep, excellent horizontal and overhead visibility, and either very short or very sparse emergent vegetation.

Little is known about the specific food habits of the birds during migration although the habitats used by whooping cranes for feeding have been fairly well documented. Whooping cranes have been observed feeding on shoots of emerging winter wheat in Texas, Oklahoma, and Nebraska. Five cranes were seen feeding actively from fresh cow droppings in Oklahoma. The birds appeared to be eating heads of milo which had passed through the cattle relatively intact. Cranes have been seen eating waste milo in a recently harvested field in Texas. On several occasions in North Dakota, birds have been observed feeding on wheat from windrows and waste spills. Cranes have also been seen feeding on waste barley in North Dakota and waste corn in Nebraska.

The importance of animal foods in the diet of whooping cranes during migration is not known, but animal matter is known to constitute part of the diet. Swenk (1933) indicated cranes were "to be seen feeding in the lagoons on aquatic plants and animals, in the hay meadows or fields on insects, and, in the autumn, on the waste grains and insects in the wheat stubble fields." Prairie settlers in Nebraska recounted observations of whooping cranes feeding on the egg masses of frogs and toads in buffalo wallows, and turning over cattle chips to obtain beetles (Allen 1952). In a shallow river where Allen observed cranes feeding, the only potential food items were small cyprinid, catastomid, and cyprinodontid fishes. Lahrman (1976) reported that fish were captured by whooping cranes at a site in Saskatchewan. J. Scrafford (pers. comm.) observed one of the adults of a family group capture, kill, and partially consume a large carp from a pond in the Rainwater Basin Area of south central Nebraska. The juvenile of the family also consumed a portion of the fish. The birds caught several more fish, frogs, and crayfish. Earthworms and salamanders also were thought to have been taken by these cranes. A farmer in North Dakota watched one whooping crane from a group of four kill a snake in a small grain stubble field and proceed to swallow it intact (T. Anderson, pers. comm.).

Table 6. Habitat types used by feeding whooping cranes during migration through the Great Plains.

Habitat type	No. of observations		
	Spring	Fall	Total
Upland sites			
Milo stubble	1	3	4
Wheat stubble	9	14	23
Barley stubble	1	2	3
Corn stubble	5	7	12
Unidentified small grain stubble	9	4	13
Emerging wheat	3	11	14
Strips of emerging wheat and standing milo	0	5	5
Milo (crop status undetermined)	0	3	3
Wheat (crop status undetermined)	0	6	6
Corn (crop status undetermined)	1	1	2
Disced agricultural field	3	3	6
Summer fallow field	0	1	1
Tame pasture	2	2	4
Subirrigated meadow	1	3	4
Subtotal	35	65	100

(continued)

Table 6. (Continued).

Wetland sites[a]			
Type 1 wetland	2	0	2
Type 3 wetland	0	2	2
Type 4 wetland	0	1	1
Type 5 wetland (freshwater)	0	1	1
Irrigation tailwater pit	1	0	1
Artificial reservoir	0	5	5
Playa lake	0	1	1
Inland salt marsh	0	3	3
Alkaline lake	0	1	1
Shallow river	0	2	2
Subtotal	3	16	19
Total	38	81	119

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[a] Classification of wetlands follows Martin et al (1953).

Although information on their food habits is limited, it is apparent that whooping cranes utilize both plant and animal foods during their migration through the midcontinent region. Although the proportions of plant and animal food in the diet are not known, it is probable that whooping cranes, like the sandhill cranes, require some animal matter to satisfy their nutritional needs. A major part of the whooping crane's energy requirements during migration across the Great Plains probably comes from waste agricultural crops.

Roost Sites

Shallow river channels represent one of several types of habitat used for roosting by whooping cranes. An evaluation of 10 documented whooping crane roosting sites on rivers identified the following characteristics as being present:

(1) wide channel, with 9 of 10 sites being between 155 and 365 m (170 and 400 yards);

(2) slow flow, i.e. approximately 0.4-1.8 ms^{-1} (1-4 mph) although water in the main channel may be flowing faster;

(3) shallow water except in the main channel (all sites evaluated were <30 cm (12 inches) deep and six of nine sites were 5-15 cm (2-6 inches) deep);

(4) unvegetated;

(5) fine substrate, usually sand;

(6) good horizontal visibility unobstructed from river bank to river bank and at least a few hundred yards upstream and downstream (or to a bend in the river) at all sites;

(7) good overhead visibility without tall trees, tall and dense shrubbage or high banks near the roost;

(8) close proximity (usually <1.6 km or 1 mile) to suitable feeding sites,

(9) isolation (0.4 km or 0.25 mile) from roads, houses, and railroad tracks; and

(10) the presence of a certain type (described below) of sandbar near the middle of the river.

All roost sites evaluated had sandbars although the number and size varied among sites. Sandbars in the vicinity of the roosts usually sloped gradually into the water (often less than 1-2°), had low topographic relief (often less than 0.3 m (1 foot)), no banks over several cm high, and had little or no vegetation.

Whooping cranes loaf on the sandbars and roost in the adjacent shallow, quiet water. Because of their position near the center of the river, these sandbars are apparently more secure from the approach of potential terrestrial and avian predators than are areas near the river's edge.

WATERFOWL

Introduction

During the past 50 years several species of waterfowl have undergone notable shifts in migrational and wintering distributions in response to manipulation of coastal and inland water resources and upland habitats (Buller 1975). This process has been particularly evident in the Central Flyway where agricultural development has caused the loss of extensive wetland habitat and the creation of new food resources. Habitat alteration has caused increased waterfowl use of the remaining traditional habitats and occupancy of man-made habitats such as reservoirs.

Waterfowl use of wintering and staging areas at middle and northern latitudes has received limited study. Little is known about the tens of thousands of mallards now wintering at midcontinent latitudes although these birds represent an increasingly important part of annual harvests in the central states (Grieb and Boeker 1954; Geis 1971). Of particular concern is the influence of wintering at northern latitudes on the physical condition of birds and the potential impact on reproduction. Krapu (1981) has shown that the physical condition of breeding female mallards is an important determinant of their capacity to reproduce. Physical condition is even more critical for species such as the white-fronted goose which arrive on arctic breeding grounds before food resources become available. It has been shown previously that stored nutrient reserves contribute substantially to the reproductive needs of lesser snow geese (Ankney and MacInnes 1978) and Canada geese (Raveling 1979).

The effects of weather on behavior, physical condition, and mortality of wintering and staging waterfowl in the Great Plains have received limited attention. Elsewhere, weather has been shown to affect the availability of open water and food resources and to influence movements and behavioral patterns within and among various habitats (Lefebvre and Raveling 1967; Reed 1971; Raveling et al. 1972; Bennett and Bolen 1978).

Because of the importance of the study area as a wintering and staging site for certain species of waterfowl, studies were undertaken to determine distribution and abundance patterns, to identify food habits of certain key species, and to assess the adequacy of the available diet in meeting nutritional requirements.

Distribution and Abundance

The Platte River Valley is an important early spring staging area for the midcontinent populations of mallards, white-fronted geese and Canada geese. Several thousand mallards and Canada geese also winter along the River. Spring migration begins in late February and early March with the exact arrival date dependent on weather conditions and availability of open water. Waterfowl tend to utilize the Platte River early in the season and move to the Rainwater Basin Area when it becomes ice-free.

Mallards and Canada geese account for most of the winter waterfowl use on the study area. Mallards winter at several sites along the

Platte River between Chapman and Kingsley Dam; over 85% of the use occurs between Grand Island and Lexington. Largest numbers occur during years of mild weather and little snow cover. Mallard distribution and abundance during the winter months of 1979 and 1980 are shown in Appendix E. The distribution of mallards varies with the extent of ice-free riverine habitat. During the extremely cold winter of 1978-79, mallards were dispersed along much of the river during December but by February many of the birds had departed to areas farther south; most of the remaining birds were in drainage canals near Overton, with smaller numbers found about 11.3 km (7 miles) east of Kearney. Milder weather during the following winter caused much of the river channel to remain open. Mallards were more dispersed along the River during the 1979-80 winter but the major concentration remained in the Overton area.

Canada geese also winter along several reaches of the Platte River (Appendix E). The primary wintering sites are between Gibbon and Lexington with the highest numbers of geese occurring between Elm Creek and Lexington where warm water discharge from power plants adjacent to the Tri-County Canal maintains open areas throughout the winter months.

Habitat Use

Mallards utilize wetland habitats on the study area during most of the year. In winter, use is largely restricted to major channels of the Platte River and those nearby irrigation canals which remain open. Seventeen radio-marked individuals monitored in the Overton-Lexington reach during January and February 1980 either roosted in wooded river channels or in irrigation canals, depending on weather conditions. Under favorable conditions, birds preferred riverine habitats with extensive open water areas, however, some individuals utilized canals throughout the winter. Most mallards left the roost sites once a day, usually in late afternoon, and flew to forage in cropland. When a storm was imminent, feeding flights would begin earlier in the day and continue until the onset of the storm. These birds apparently attempted to secure adequate food to compensate for the diminished feeding opportunities during and after the storm.

The availability of suitable feeding conditions influenced the distance mallards traveled during feeding flights. During the mild winter of 1979-80, mallards generally remained within 3.9 km (2.4 miles) of the river, whereas during the harsh winter of 1978-79, with food scarce because of heavy snow accumulations, mallards flew up to 21 km (13 miles) from the river to feed. Snow accumulation that winter made corn inaccessible to mallards, except where grazing cattle broke up the snow and ice. There was little snow cover during the 1979-80 winter, markedly increasing access to food supplies; this change was reflected in time spent foraging. Mallards spent 78% of the time feeding while in grazed cornfields during 1978-79, and only 52% during the following year. During the first year of the study birds spent more time feeding to compensate for heavy snow cover that reduced access to corn.

Roost fidelity was strong during cold weather when fewer suitable habitats were available; movement among and within habitats increased during warm weather. Yearling ducks tended to change habitats more often and have larger home ranges than did adults, presumably reflecting inexperience in securing their needs.

Mallards preferred rainwater basins when wetlands became ice-free. The birds generally utilized the deeper basins for nocturnal roosting and moved to nearby agricultural fields for diurnal roosting and foraging. Mallards moved back to the Platte during intermittent cold periods when the basins froze. In March 1980, several radio-marked individuals, which had taken up residence in the Rainwater Basin Area in late February temporarily returned to their winter roost sites on the Platte. While in the Rainwater Basin Area, mallards made relatively short daily feeding flights from wetlands to surrounding cornfields. Mallards typically fed with other dabbling ducks and geese. The length of feeding flights gradually increased as the staging period progressed, presumably because nearby food resources became scarce due to intensive foraging activity by waterfowl.

White-fronted geese typically arrive in south central Nebraska in late February when snow cover is present and basins are frozen. Under these conditions, geese initially congregate in open reaches of the Platte between Lexington and Grand Island and make daily morning and afternoon flights to adjoining cornfields to feed with the large numbers of Canada geese and mallards that are present at that time. With opening of the Rainwater Basins, most of the white-fronted goose population shifts to the Basin Area. Feeding flights radiate out from the basins to nearby corn and winter wheat fields. White-fronted geese typically make a morning and afternoon feeding flight.

Feeding Ecology

Waste corn appears to be the dietary staple of most dabbling ducks and geese during the annual stopover in south central Nebraska. The winter diet of mallards consisted principally of foods taken on agricultural lands. Five plant foods (foxtail, sorghum, corn, smartweed, and barnyard grass) accounted for over 99% of their diet (Fig. 14). Corn accounted for 97% and 94% of the diet of drakes and hens, respectively. Unharvested sorghum became a relatively important item in the diet during the 1978-79 winter when seed stalks were accessible above the snow cover and access to corn was restricted.

Animal matter, primarily snails, formed less than 1% of the diet of mallards. Birds fed almost exclusively on corn when foraging in grazed corn stubble, whereas aquatic plant seeds and animal matter came principally from riverine habitats. About 55% and 45% of the daylight hours were spent feeding while in riverine habitats during the 1978-79 and 1979-80 winters, respectively. These data suggest that mallards fare well on a diet that is principally corn but small quantities of animal matter are needed to meet nutritional requirements.

The diet of female mallards during the spring staging period differed only slightly from the winter months with almost no change in the proportion of animal matter consumed (Fig. 14). These data support previous evidence

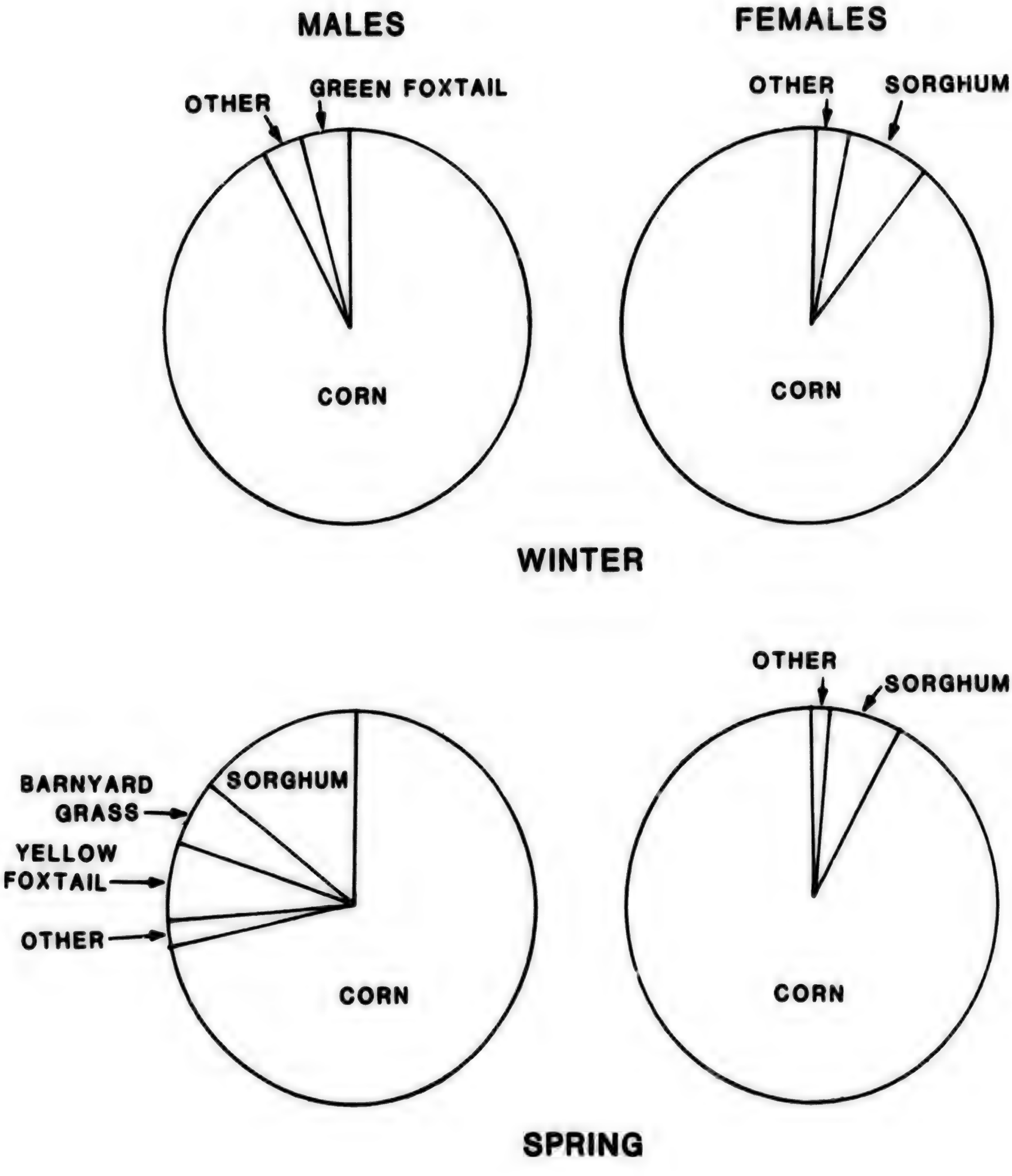

Fig. 14. Diet of male and female mallards during winter and spring migration in south central Nebraska.

that mallards rely principally on food acquired on the breeding grounds to meet the substantial protein and calcium requirements for reproduction (Krapu 1979).

Field feeding by white-fronted geese occurs primarily in corn and winter wheat fields. Corn occurred in the following proportions in the diet by sex and age group: adult males, 76.9%; juvenile males 98.0%; adult females, 90.9%; and juvenile females, 98.5%. The corn in the diet is from waste kernels remaining in the fields after harvest; green shoots of winter wheat form the other principal component of the diet. The birds probably take some animal matter from Basin wetlands to meet calcium and protein requirements but further study is needed to identify the contribution of wetland foods to the diet of white-fronted geese.

Fat Storage

The study area serves as a major conditioning site for spring staging waterfowl. White-fronted geese, for example, arrive relatively lean but undergo a marked increase in body weight and fat content during March and early April (Fig. 15). Fat levels among males and females increased at a daily rate of 12.5 and 17.6 g, respectively. Assuming a 30 day stopover, lipid deposition among males and females averaged 375 and 528 g, respectively.

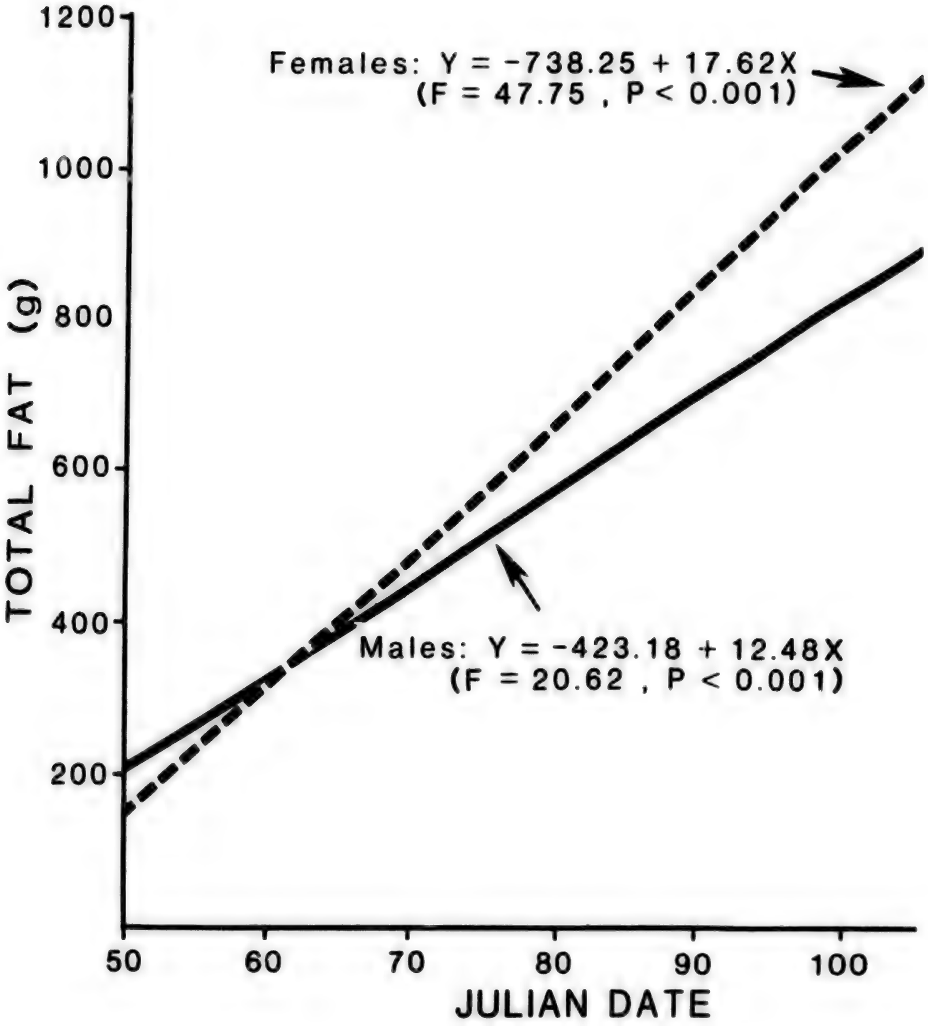

Fig. 15. Daily rates of fat deposition among adult male and female white-fronted geese during the spring staging period in south central Nebraska.

BALD EAGLES AND OTHER RAPTORS

Introduction

The Central Plains States (South Dakota, Nebraska, Kansas, and Oklahoma) account for more than 1500 of the 8300+ bald eagles wintering in the 48 contiguous states (Lincer et al. 1979). Wintering concentrations of this species in the midcontinent region are associated primarily with river systems. Because of the endangered status of the bald eagle, there has been an increasing need to identify its winter habitat requirements. Several recent investigations have increased our knowledge of the winter ecology of this species (Edwards 1969; Vian 1971; Lish and Lewis 1975; Steenhof 1976; Hansen 1977; Griffin 1978).

Although the Platte and North Platte Rivers in Nebraska have been identified as an important wintering ground of the bald eagle (Shickley 1961; Vian and Bleise 1974), limited information has been available on population distribution and abundance, habitat use, and feeding ecology. Therefore, a major emphasis was placed on obtaining such information as part of present investigations in order to identify habitat requirements and to develop guidelines for management of bald eagle habitat on the study area.

Lands within the Platte River Valley also host numerous other raptors during the winter. Previous studies have described species composition and winter densities of birds of prey in portions of Nebraska (Mathisen and Mathisen 1968; Craighead and Craighead 1969; Lock 1972, 1974) but there has been a general lack of information concerning the distribution and abundance of raptors in relation to specific habitat types and areas within the Platte River Valley.

Distribution and Abundance

Sixteen species of raptors were observed on the study area from 1978-80 including the endangered bald eagle and the peregrine falcon. The number and species composition of raptor sightings by reach of river are shown in Appendix F. A total of 12 species were sighted along 265 km (164 miles) of survey routes that were censused semi-monthly and monthly during the 1978-79 and 1979-80 winters, respectively. The bald eagle was the most numerous species with peak wintering populations estimated to be 150 and 250 birds during the 1978-79 and 1979-80 winters, respectively. The other principal raptors, in decreasing order of abundance, were the red-tailed hawk, American kestrel, marsh hawk, rough-legged hawk, prairie falcon, ferruginous hawk, and golden eagle. Incidental sightings included four separate observations of peregrine falcons, three of merlins, and 10 of golden eagles. Three species of owls were observed during surveys: the great-horned owl, screech owl, and short-eared owl.

The density of raptors wintering in the Platte and North Platte River Valleys declined from 0.46 birds/km (0.73 birds/mile) of survey route in 1978-79 to 0.39 birds/km (0.63 birds/mile) in 1979-80. Densities of bald eagles, rough-legged hawks, and sharp-shinned hawks increased during the latter winter whereas densities of red-tailed hawks, kestrels, marsh hawks, prairie falcons, ferruginous hawks, and golden eagles declined. Species differences appear related, in part, to marked yearly variation of weather conditions. The 1978-79 winter was extremely cold with a substantially greater snow cover than existed during the following winter. Mild conditions during 1979-80 caused most species to disperse because of improved foraging conditions. The bald eagle population, however, increased by approximately 50% during the 1979-80 winter because river channel conditions were more favorable for foraging than during the previous winter.

Bald eagles were observed throughout the 327 km (203 miles) of river channel during the study. However, densities varied widely among reaches of river (Fig. 16). Based on evening counts of individuals returning to communal roosts, the largest concentrations were on Jeffrey's Island (roost F) near Lexington and at two sites below Kingsley Dam (roost B). The number of bald eagles per roost, characteristics of roost sites, and roost locations are given in Appendix G.

Habitat Use

Raptors wintering in the Platte River Valley were most often associated with riparian woodlands; 44% of the sightings were recorded in this habitat type (Table 7). Habitat use varied widely among species. Buteos, particularly the bald eagle and red-tailed hawk, tended to use shelterbelts and woodlots whereas the ferruginous hawk, prairie falcon, American kestrel, and marsh hawk frequented tilled fields and mowed haylands. Irrigation ditches, and grazed and ungrazed pastures each accounted for less than 6% of the raptor sightings.

Bald eagles typically resided in riparian habitat (Table 7). However, eagles ranged widely from the river channel during the 1978-79 winter, apparently in search of food.

Bald Eagle Feeding Ecology

Bald eagles have a diverse diet while wintering along the Platte and North Platte Rivers in Nebraska. Analyses of the 2858 regurgitated pellets collected at 11 communal night roosts and several feeding perches during the 1978-79 and 1979-80 winters indicated the diet included 23 species of birds and 22 species of mammals (Appendix H). The most frequently occurring foods, by major taxa, were: birds, 76.5%; mammals, 33.8%; fish, 10.8%; and other, 0.3%. The principal prey species (by percent occurrence) were: mallard, 37.0%; eastern cottontail, 9.1%; Canada goose, 8.0%; carp, 5.0%; and meadow vole, 2.6%.

Although search efforts were comparable during the 2 years and despite a 67% increase in bald eagle numbers, only 793 pellets were collected at roost sites in 1980 as compared to 1989 pellets collected in 1979. The lower rate of pellet formation during the second year appears due to differences in diet. General observations indicated that eagles preyed more heavily on fish during the 1979-80 winter. Fish are more digestible than birds and mammals so fewer pellets are produced (Lish 1973). When fish were observed in pellets, their presence was indicated only by a few scales amid either hair or feathers. Less than

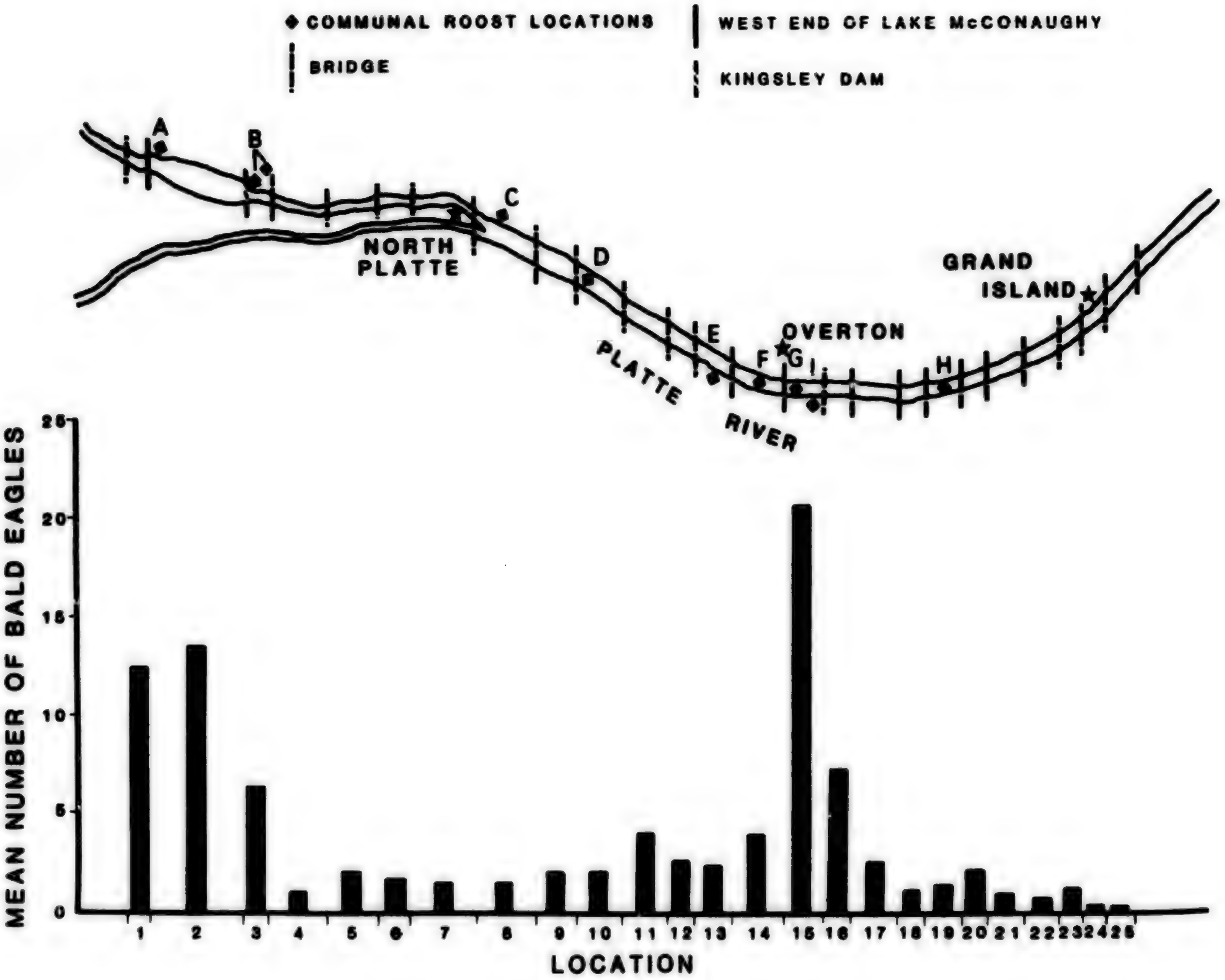

Fig. 16. Distribution of communal roosts of bald eagles on the study area and average number of eagles sighted between bridges based on aerial surveys during the 1978-79 and 1979-80 winters (see Appendix G for additional details).

Table 7. Habitat use by raptors during the 1978-79 and 1979-80 winters in the North Platte and Platte River Valleys.

Habitat type	Red-tailed hawk	Rough-legged hawk	Ferruginous hawk	Bald eagle	Prairie falcon	American kestrel	Marsh hawk	All species
Riparian woodlands								
Birds observed	311	38	7	838	7	40	35	1476
% in habitat	53.6	17.1	14.0	75.9	8.4	8.6	14.2	43.7
Shelterbelts-woodlots								
Birds observed	127	45	9	201	6	64	6	530
% in habitat	21.9	20.3	18.0	14.8	7.2	13.8	2.4	15.7
Grazed pasture								
Birds observed	23	40	4	38	9	35	25	196
% in habitat	4.0	18.0	8.0	2.8	10.8	7.5	10.2	5.8
Ungrazed pasture								
Birds observed	14	12	1	20	3	26	33	128
% in habitat	2.4	5.4	2.0	1.5	3.6	5.6	13.4	3.8
Tilled field								
Birds observed	38	31	20	154	31	151	54	515
% in habitat	6.6	14.0	40.0	11.4	37.3	32.5	22.0	15.2
Mowed field								
Birds observed	47	40	7	37	21	84	39	285
% in habitat	8.1	18.0	14.0	2.7	25.3	18.1	15.8	8.4

(continued)

Table 7. (Continued).

Irrigation canal								
Birds observed	13	8	--	35	4	33	25	132
% in habitat	2.2	3.6	--	2.6	4.8	7.1	10.2	3.9
Other								
Birds observed	7	8	2	30	2	31	29	118
% in habitat	1.2	3.6	4.0	2.2	2.4	6.7	11.8	3.5
Total	580	222	50	1353	83	464	246	3380

3% of the pellets were composed solely of scales. Therefore, the level of fish occurrence in the diet is underestimated from pellet analyses, emphasizing the need to also consider field observations of foraging patterns.

Eagle food habits were strongly influenced by prey availability. Other vertebrates formed a relatively low proportion of the diet when riverine conditions caused fish to be readily accessible. However, when either ice cover or high flows prevented eagles from obtaining fish, alternative prey were taken. Waterfowl dominated the diet during the 1978-79 winter when only limited ice-free channel habitat remained and snow cover was present. Observations indicated many of the waterfowl eaten were scavenged from other raptors. Bald eagles were observed stealing waterfowl remains from other raptors (klepto-parasitism) on at least 12 occasions during the 1978-79 winter and only twice during the 1979-80 winter; the importance of waterfowl in the diet of bald eagles declined markedly during the latter winter. Bald eagles were observed pirating mallards from ferruginous hawks, golden eagles, and other bald eagles. Carrion also was an important component of the diet under severe conditions during the 1978-79 winter. Several reports were received of eagles feeding on dead cattle left in fields along the river during that winter whereas no reports were received during the winter of 1979-80. The close proximity of the River to I-80 results in substantial carrion being available to eagles as a result of mortality from motorized vehicles. Deer losses are substantial and contribute to the winter diet of eagles. Bald eagles also took advantage of winter-killed fish which became available during the spring melt. Observations of klepto-parasitism ended in early spring when alternative food sources became available. Bald eagles were never observed capturing live prey other than fish but were observed carrying or feeding on freshly killed carcasses of mallards, Canada geese, and blacktail jackrabbits on several occasions.

Prey availability varied from west to east. The eastern cottontail, for example, was more abundant at easterly sites, and was more prevalent in the diet there. Conversely, other species such as pronghorn and mule deer were more abundant in the west and were identified in pellets only at western roosts.

Marked temporal shifts in diet followed changes in prey availability. During the 1979-80 winter, for example, pellet numbers at roost sites increased markedly during late February and March as eagles shifted from a predominantly fish diet to one dominated by birds and mammals. This change was associated with high water conditions which apparently impeded eagle foraging success on fish. Pellet numbers increased from a low of 22 between 29 January and 11 February to a peak of 281 during 11-24 March while flows in the Platte at Overton increased from 44-72 m^3/sec to 71-88 m^3/sec, respectively. Field observations of eagles pursuing birds and mammals increased during the period of high flows while observations of eagles pursuing fish diminished. Blacktail jackrabbits became a major food item in the diet when high flows impeded access to fish. Jackrabbits occurred in 21% of the pellets during the 1979-80 winter in comparison to <1% the previous year. Pellet data were complemented by regular observations of bald eagles in pursuit of jackrabbits in the

Overton Area. Under improved foraging conditions during the 1979-80 winter, klepto-parasitism diminished greatly suggesting that it occurs primarily in times of stress when alternative prey are scarce.

The diet of eagles varied among the roosts (Fig. 17). Waterfowl formed a high proportion of the diet at those sites where numerous mallards and Canada geese were present, i.e., below Kingsley Dam and downstream from the warm-water return flows from the Tri-County Diversion Canal (sites E thru I). Mammals formed a greater proportion of the diet in areas where fish and waterfowl were less available.

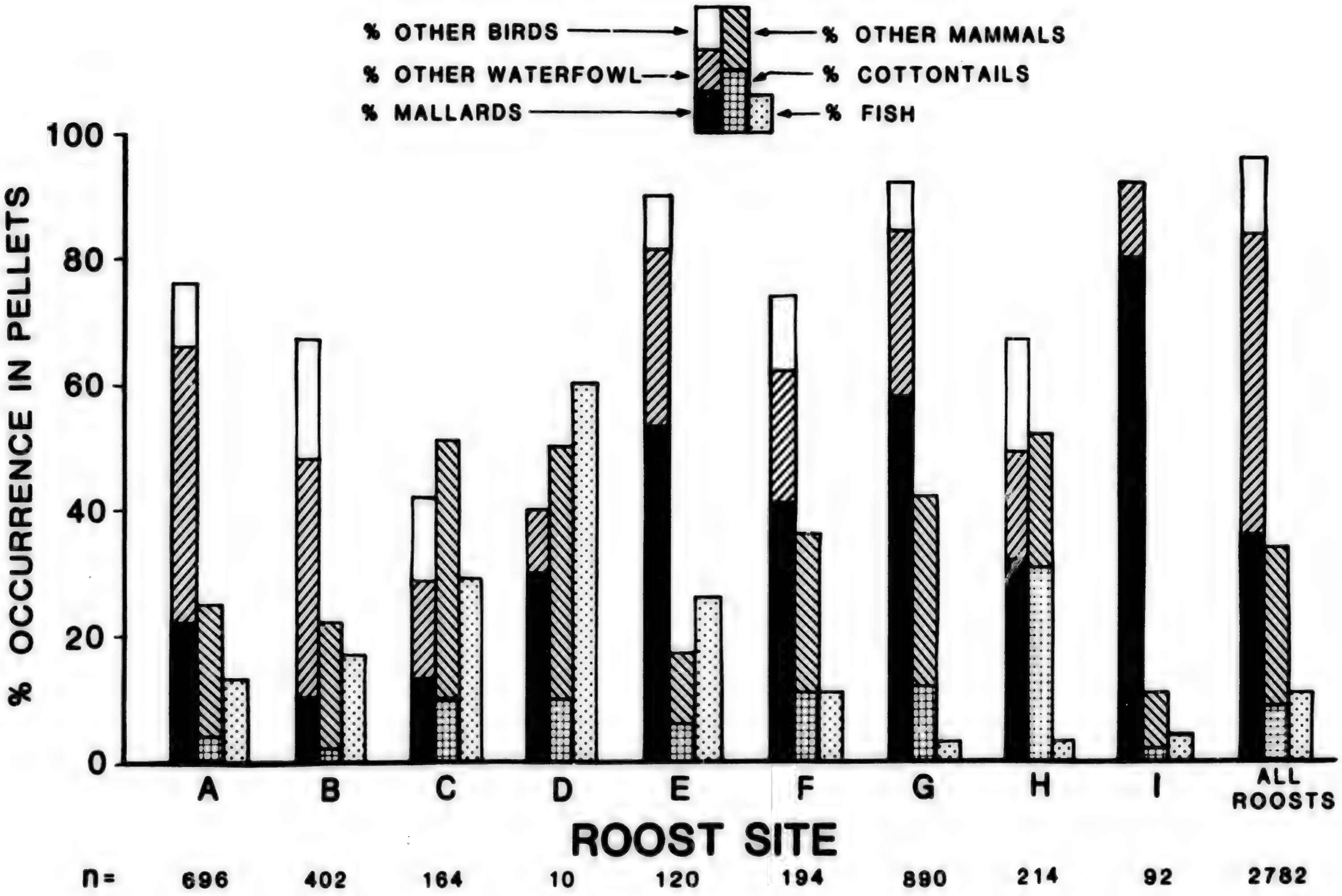

Fig. 17. Occurrence of prey items in egested pellets of bald eagles found at roost sites along the Platte and North Platte Rivers.

BREEDING BIRDS

Distribution and Abundance

A total of 142 species of birds were recorded breeding on the study area during studies in 1979 and 1980. These records represent nearly 71% of the species breeding in Nebraska. The projected mean breeding population on the study area was estimated at about 2,900,000 pairs. By taxonomic order, in decreasing abundance, the most common groups of birds were Passeriformes, Columbiformes, Apodiformes, and Piciformes. These four orders accounted for 95% of the total breeding bird population. Fifteen families accounted for 95% of the total population; blackbirds (Icteridae) and sparrows (Fringillidae) were the most frequent families encountered, about 52% of the total. Weaver finches (Ploceidae), doves (Columbidae), flycatchers (Tyrannidae), thrushes (Turdidae), and swifts (Apodidae) composed an additional 26% of the bird population on the study area.

Thirty-four species accounted for approximately 95% of the total bird population (Table 8). Western meadowlarks, common grackles, and grasshopper sparrows constituted approximately 26% of the population with each having 248,000+ breeding pairs. House sparrows, mourning doves, and brown-headed cowbirds formed about 19% of the total population. The remaining 28 species were each represented by breeding populations that totaled less than 150,000 pairs.

Among the remaining species are several of special interest or having very limited breeding ranges. Included in this group are the burrowing owl, greater prairie chicken, long-billed curlew, and piping plover.

Burrowing owls occurred on only four census plots. Habitat use was restricted to upland native prairie in both the Sandhill Region and on fine textured soils in other areas. This species has been included for years on the Blue List, a system developed by the National Audubon Society to function as an early warning for species which may be approaching a critical status (Arbib 1978). The projected breeding population of burrowing owls on the study area was 3800 pairs.

Greater prairie chickens occurred on upland native prairie on sandhill soils. This species is nationally threatened (U.S. Bureau of Sport Fisheries and Wildlife 1973), endangered in certain areas and extirpated over most of its former range. An estimated 3800 pairs were present on our study area although none were present on plots in the Platte or North Platte River Valleys.

Long-billed curlews occurred on upland native prairie on both sandhill and fine textured soils. The greatest breeding density occurred in sandhill prairie. This species formerly bred throughout the prairie regions of North America, but its range is now markedly reduced (McCallum et al. 1977). The projected population on our study area was 2600 pairs. The breeding status of the piping plover is also of continental concern (Arbib 1978). The projected Platte River population was 120 breeding pairs.

Table 8. Estimated populations of the principal species of birds breeding on the study area.

Species	Predominant habitat[a]	Population estimate	Percent of total population
Western Meadowlark	NG, WM	302,500	10.2
Common Grackle	R	251,000	8.5
Grasshopper Sparrow	NG	248,500	8.4
House Sparrow	R	214,500	7.3
Mourning Dove	LF	180,000	6.1
Brown-headed Cowbird	S	175,500	6.0
Red-winged Blackbird	NBW	148,000	5.0
American Robin	S	120,000	4.1
Lark Bunting	W	103,500	3.5
Western Kingbird	S	98,500	3.3
Chimney Swift	R	95,000	3.2
Horned Lark	NG	87,500	3.0
Starling	R	85,000	2.9
Dickcissel	A	69,500	2.3
Eastern Kingbird	S	65,000	2.2
Barn Swallow	RCI	60,500	2.0
Northern Oriole	S	56,000	1.9
Lark Sparrow	NG	51,000	1.7
Common Flicker	S	47,000	1.6
House Wren	S	45,500	1.5
Bobolink	WM	43,500	1.5
Upland Sandpiper	WM	31,500	1.1

(continued)

Table 8. (Continued).

Red-headed Woodpecker	S	29,000	1.0
Brown Thrasher	S	26,000	0.9
Orchard Oriole	S	25,000	0.8
Cliff Swallow	RCI	20,000	0.7
Killdeer	RCI	19,500	0.7
Yellow Warbler	S	19,000	0.6
American Goldfinch	RCI	19,000	0.6
Ring-necked Pheasant	WM	16,500	0.5
Common Yellowthroat	RCI	16,500	0.5
Common Nighthawk	NG	14,500	0.5
Bobwhite	LF	10,500	0.3
Blue Jay	LF	7,000	0.2

[a] Predominant habitats include native grassland (NG), wet meadow (WM), lowland forest (LF), shelterbelt (S), river channel island (RCI), alfalfa field (A), wheat field (W), residential (R), and natural basin wetland (NBW).

Habitat Affinities

Characteristic species breeding in each of the major natural habitat types of the Platte River Valley are shown in Fig. 18. Bird communities of both natural and man-created habitats on the study area are described in this section.

Shelterbelts

The highest densities of breeding birds on the study area were in shelterbelts (1361 pairs/40.5 ha or 100 acres). Shelterbelts were used by 31 species; 27 of these were considered nesting species. Twenty-five species attained their highest density in shelterbelts; mourning dove, common grackle, brown-headed cowbird, and northern oriole were most abundant.

River channel islands

Wooded islands in channels of the Platte River also received high use by breeding birds. Forty-seven species were recorded on river channel islands, and 35 were considered breeders. Mean density of breeding pairs was 212.4 pairs/40.5 ha (100 acres). The cliff swallow and common yellowthroat were the most numerous species. Piping plover, belted kingfisher, willow flycatcher, bank swallow, cliff swallow, Bell's vireo, common yellowthroat, cardinal, and indigo bunting attained their highest density on river channel islands. The piping plover was restricted exclusively to unvegetated and sparsely vegetated sandbars.

Lowland forest

Lowland forest supported the greatest number of species on the study area. A total of 64 species were present; 50 were considered to be nesting. Fourteen species reached their maximum population density in this habitat type. The most abundant species were house wren, mourning dove, American robin, and brown-headed cowbird. Eastern phoebe, eastern wood pewee, Bewick's wren, eastern bluebird, blue grosbeak, lazuli bunting, and rufous-sided towhee occurred only in this habitat type. The mean density of breeding birds was 202.4 pairs/40.5 ha (100 acres).

Lowland native prairie

Thirty-five species were recorded in lowland native prairie and 27 of these were considered breeders. The mean density of breeding birds was 47.4 pairs/40.5 ha (100 acres). Western meadowlark, grasshopper sparrow, red-winged blackbird, and brown-headed cowbird were the most numerous species. Upland sandpiper, bobolink, and eastern meadowlark reached their highest abundance in lowland native prairie. The eastern meadowlark was the only species restricted exclusively to lowland prairie.

Upland native prairie

Fifty-one species were recorded in this habitat type; 31 were considered to be nesters. Grasshopper sparrow, western meadowlark, and

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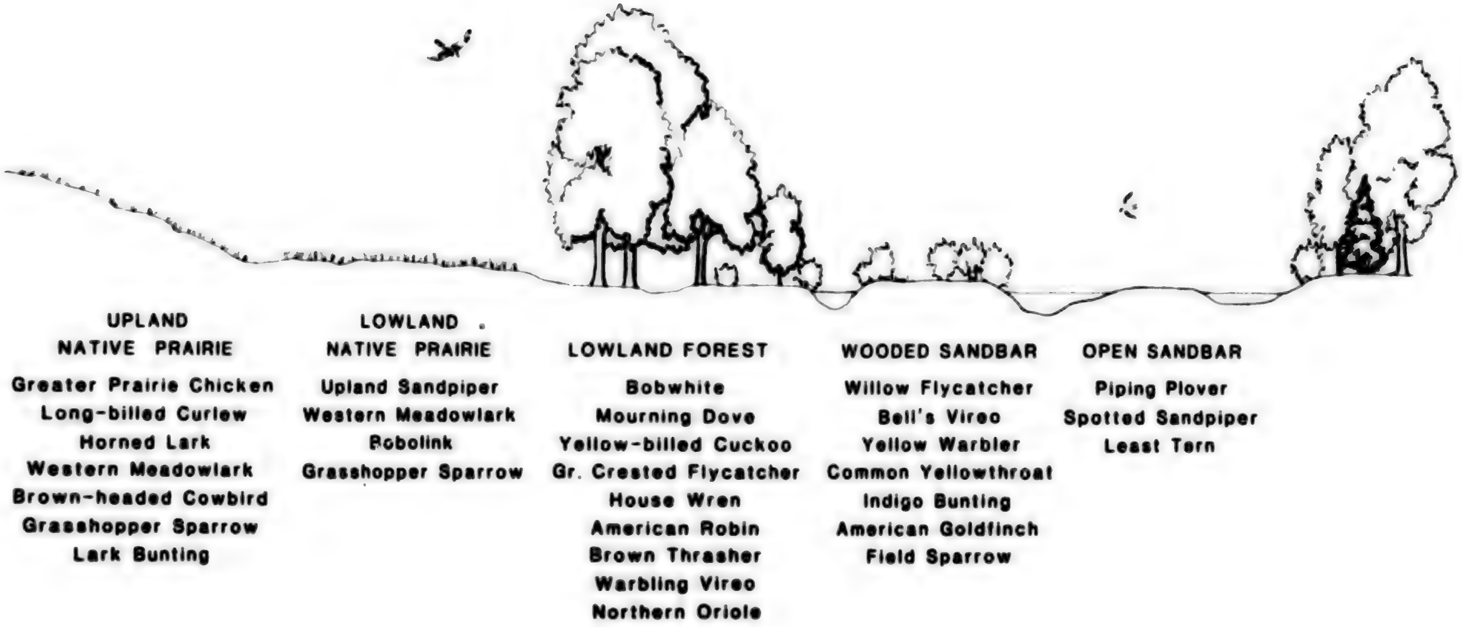

Fig. 18. A diagrammatic sketch of the principal natural habitats of the Platte River Valley and characteristic species of breeding birds.

dickcissel were the most abundant species. Swainson's hawk, greater prairie chicken, sharp-tailed grouse, long-billed curlew, great-horned owl, burrowing owl, common nighthawk, and grasshopper, vesper, lark, field, Brewer's, and Cassin's sparrows reached their highest density in upland native prairie. Six species were restricted to this habitat. Mean density of breeding birds was 39.3 pairs/40.5 ha (100 acres).

Alfalfa fields

Twenty-eight species were recorded in alfalfa fields of which 13 were considered nesting. The mean density was 41.3 pairs/40.5 ha (100 acres). Mourning dove, dickcissel, western meadowlark, and brown-headed cowbird occurred in highest densities. No species reached its maximum breeding density in alfalfa fields.

Corn and wheat fields

Eighteen species of birds were recorded in cornfields; horned lark, killdeer, and western meadowlark were considered breeders. The mean density of breeding birds was 15.3 pairs/40.5 ha (100 acres). The western meadowlark was the most numerous of the 3 breeding species. No species reached its highest density in cornfields.

Thirteen of 15 species recorded in wheat fields were considered to be nesting. The mean breeding density was 13.4 pairs/40.5 ha (100 acres), the lowest recorded for any habitat type on the study area. Lark bunting, western meadowlark, and the grasshopper sparrow were most abundant. Only one species, the lark bunting, reached its highest population density in wheat fields.

EFFECTS OF HABITAT ALTERATION ON MIGRATORY BIRDS

Sandhill Cranes

Impact of channel habitat deterioration on distribution

The gradual encroachment of woody vegetation in conjunction with receding channel width has caused a marked shift in the distribution of sandhill cranes along the Platte River. The present distribution of sandhill cranes is shown in Fig. 7. Although there is a paucity of information on crane distribution before the era of water development the birds probably utilized most of the Platte in south central Nebraska. The river was formerly wide, shallow, and bordered by meadows throughout its length within the study area.

Observations published by Walkinshaw (1956) indicate that by 1954 sandhill crane distribution along the Platte River was largely restricted to the reach between Cozad and Grand Island, a distance of 150 km (93 miles). Large numbers of cranes remained at that time in the Cozad-Lexington Area. By 1979, cranes had abandoned an additional 37 km (23 miles) of the Platte and use of the river channel by cranes in the Overton-Elm Creek section was restricted to a few sites (Fig. 7). High densities of roosting cranes are now centered on staging area 1 eastward from Kearney to a few miles east of Grand Island, in the Elm Creek-Odessa reach of staging area 2, and on staging area 3 between Sutherland and North Platte (Fig. 7).

The distribution of roosting cranes along the river is influenced by both man-made and natural factors. Characteristics of river segments utilized by roosting cranes are listed in Appendix I. Bridges crossing the river and roads immediately adjacent to it have a significant ($P<0.05$) negative effect on crane use of the river. The mean number of cranes roosting on segments with bridges or adjacent roads, or both, is less than half the mean number on segments without these disturbances. Among 385 0.8 km (0.5 mile) segments of river considered in this part of the study, 61 (16%) had either a bridge or an adjacent road. Within the study area, 35 bridges cross the North Platte or Platte Rivers, and 18 of these occur within the staging areas.

The availability of wide, unobstructed sections of river channel has a highly significant correlation with the roosting distribution of cranes ($P<0.001$). Over 99% of all cranes observed roosting on the Platte and North Platte Rivers in 1979 were within 0.8 km (0.5 mile) segments with an unobstructed stretch of river at least 50 m wide; almost 70% of the cranes were in segments over 150 m wide. Only 25% of the segments studied had unobstructed channel widths of over 150 m, and 82% were over 50 m wide. The fact that crane use of segments of the river with wide stretches of open water was proportionately higher than the availability of such segments implies a preference for these areas.

The height of vegetation on river islands and along the banks of the main channel also seems to affect cranes use, with the birds apparently preferring to roost where the vegetation is short. However, preference for short vegetation does not appear to affect crane use as much as their preference for wide, open channels. When the two factors are considered together, the relationship is more easily understood. In Table 9, the 385 0.8 km (0.5 mile) segments considered are divided into three categories of unobstructed channel width and five categories of vegetation height. The first parameter indicates the width of the widest, unobstructed channel within the 0.8 km (0.5 mile) segment, and the latter reflects the mean of the predominant height classes of vegetation on the north, south, and island banks within that segment. Each cell of the table, therefore, represents a different combination of channel width and vegetation height. Each cell indicates the percent of all roosting cranes observed and percent of the 0.8 km (0.5 mile) river segments in that category. These values are also summed across the rows and down the columns. A percent use value greater than the percent availability value for that cell implies cranes prefer those conditions, whereas if use is less than availability, this would imply that cranes avoid such conditions. A chi-square analysis strongly rejected ($P<0.001$) the null hypothesis of a random distribution of cranes.

Cranes avoided all segments of river channel in which the widest available open channel was less than or equal to 50 m, regardless of vegetation height (Table 9, Fig. 19). In fact, although 18% of the 0.8 km (0.5 mile) segments were in this width class, less than 1% of the cranes roosted in these conditions. In the intermediate width category, cranes avoided all segments except where the vegetation was less than 0.5 m, in which situation a slight preference is indicated. Among segments with unobstructed channels wider than 150 m, a preference is seen in all instances, regardless of vegetation height.

The last row of Table 9, which presents the sums of the percents of all widths within each vegetation height class, shows that, when channel width is not considered, cranes tended to avoid segments where the vegetation is greater than or equal to 8.0 m in height, and they seemed to prefer areas where the vegetation is shorter, with the 4.0-7.9 m vegetation height class receiving the narrowest margin of preference (the percent difference between the values). The last column of the table sums the percents of all vegetation height classes for each width category. These data indicate that, when vegetation height is excluded, cranes strongly avoid roosting in segments of the river where the widest unobstructed channel width is less than or equal to 50 m; they also avoid, although not as strongly, segments where the open channel is 51-150 m wide; and prefer portions of the river with open channels over 150 m wide.

In summary, the combined factors of vegetation height and unobstructed channel width strongly influence the roosting distribution of sandhill cranes; they prefer river segments with channels over 150 m wide and exhibit a slight preference for channels 51-150 m wide if the predominant bank vegetation is less than 0.5 m high. Only 26% of the 0.8 km (0.5 mile) segments exhibit these characteristics, but they support 70% of the roosting population.

Land use and food requirements

Continued deterioration of the Platte River channel with further crowding of roosting areas and changes in agricultural practices could

Table 9. Percent of sandhill crane population roosting in river segments of varying width and vegetation characteristics (upper value) and the percent of river segments in each category (lower value).

Width[b] (m)	Vegetation height class[a] (m)					
	<0.5	0.5-1.9	2.0-3.9	4.0-7.9	8.0≤	Total
≤50	0.0 0.8	0.0 0.0	0.0 0.8	0.0 3.1	0.2 13.8	0.2 18.5
51-150	1.1 0.8	0.6 4.2	4.4 7.3	16.2 22.6	8.7 21.3	31.0 56.2
150<	3.2 1.0	6.5 1.6	18.9 6.2	28.3 10.4	12.0 6.2	68.9 25.4
Total	4.3 2.6	7.1 5.8	23.3 14.3	44.5 36.1	20.9 41.3	

[a] Mean height class of predominant vegetation height on north, south, and island banks.

[b] Maximum unobstructed water width/0.5 mile interval.

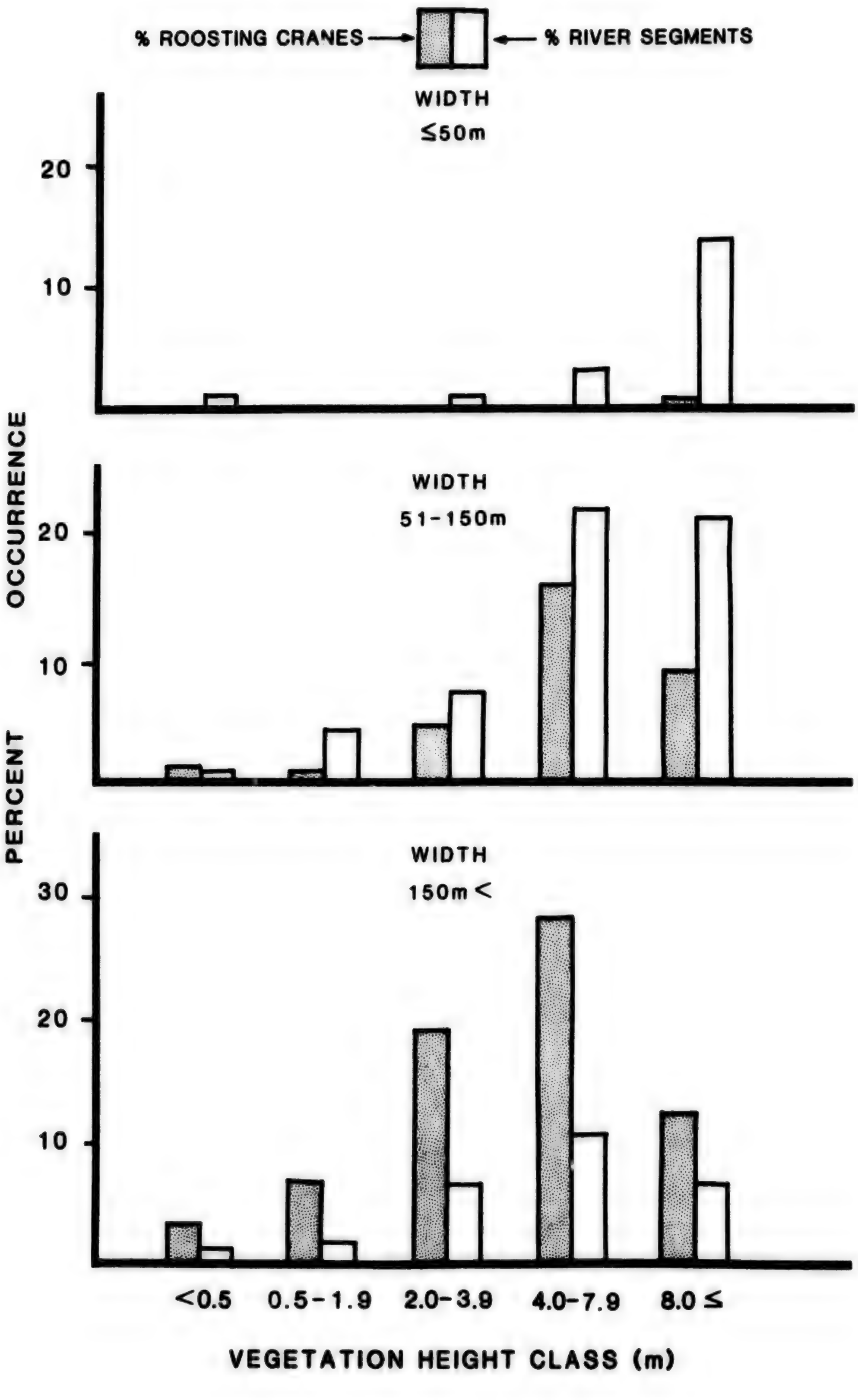

Fig. 19. Distribution of roosting sandhill cranes (by percent occurrence) among categories of unobstructed river channel width and predominant vegetation height class on adjacent channel and island banks.

have serious impacts on crane food resources. The estimates of crane food requirements (Fig. 12) and data on food availability (Table 5) provide a basis for evaluating the impact of potential future changes in land use.

If woody vegetation encroachment eliminates crane use of staging area 2 and the cranes were to shift to staging area 1, the population of staging area 1 could increase to over 400,000 birds. The population would not be limited by available food resources, however, assuming that cranes are dependent on agricultural food resources (Table 10), that cranes can utilize 50% of the waste corn on each field, that fall tillage continues at the current level of 0-25%, and that native grassland habitat remains available.

Availability of food would change drastically, however, if fall tillage increases or corn production decreases (Table 10). If fall tillage approaches or exceeds 50%, crane food resources would be seriously affected (Table 10). If this occurs, changes in crane distribution, movements, and perhaps physical condition would follow. These data underscore the highly beneficial impact upon cranes of the current practice of grazing livestock on harvested cornfields during winter because it discourages fall tillage and maintains the supply of waste corn. A shift to alternative crops could adversely affect food supply. If corn production is replaced by soybeans, for example, crane food resources probably would decline drastically. The effect of certain other crops would be less deleterious, but none provide comparable quantities of energy-rich food.

Whooping Cranes

Factors affecting trends in use of the Platte River

The number of confirmed sightings of whooping cranes on the Platte River has fallen markedly in recent decades. In the years 1890-1919 there were 17 confirmed sightings on or near the river (Allen 1952). From 1920-49 there were 65 sightings, but from 1950 through 1980 there have been only 5. Possible causes for the decrease in sightings include: (1) a decrease in the amount of effort to observe and report cranes on the river; (2) reduced visibility of cranes while on the river due to encroachment by woody vegetation; (3) a change in the population of whooping cranes; and (4) an actual decrease in use of the river by whooping cranes.

It seems doubtful that an actual decrease has occurred in efforts to observe and report cranes along the Platte. Although biologists Swenk, Brooking, and Allen actively solicited firsthand observations from 1912 through 1948, there has been a marked rise in public interest in observing cranes in the Platte River Valley. Personnel of the Nebraska Game and Parks Commission and the U.S. Fish and Wildlife Service also have monitored crane activity in recent years. Although encroachment by woody vegetation in recent decades has markedly reduced visibility on the river channel, this has been offset, at least in part, by improved access to fields adjoining the river. Therefore, it seems probable that whooping cranes have as much chance of being detected now as in years past.

Table 10. Hectares of harvested corn stubble necessary to support the sandhill crane population under various conditions.

Staging area	Hypothetical crane population (thousand)	Food requirement (10^3 kg corn)	Area of cornfields (10^3 ha) required assuming corn removed is			Area of cornfields (10^3 ha) available assuming fall tillage is[a]			
			100%	75%	50%	75%	50%	25%	0%
1	207	609	3.0	4.0	5.9	8.8	14.9	21.0	27.1
	276	813	4.0	5.3	7.9				
	345	1016	5.0	6.6	9.9				
	414	1219	5.9	7.9	11.9				
2	39	112	0.5	0.7	1.1	3.0	5.0	7.0	9.1
	52	150	0.7	1.0	1.5				
	65	187	0.9	1.2	1.8				
	78	224	1.1	1.5	2.2				
3	54	155	0.8	1.0	1.5	1.6	2.7	3.8	4.9
	72	206	1.0	1.3	2.0				
	90	258	1.3	1.7	2.5				
	108	310	1.5	2.0	3.0				
Combined	300	876	4.3	5.7	8.5	13.4	22.6	31.8	41.1
	400	1169	5.7	7.6	11.4				
	500	1461	7.1	9.5	14.3				
	600	1753	8.6	11.4	17.1				

[a] Assumes that tillage reduces corn availability by approximately 90% (Frederick 1979:50-52).

Changes in size of the whooping crane population do not appear to account for the decrease in sightings. The total population of migratory whooping cranes was declining from 1890 through 1941, over which time there was an increase in sightings along the Platte. From 1942 to spring 1980, the wild population which migrates through the Great Plains increased from an estimated 15 (Allen 1952) to 76 birds (K. Johnson, pers. comm.). Yet the number of sightings on or near the Platte River fell markedly during this period.

Available evidence suggests there has been an actual decrease in the use of the Platte River by whooping cranes during the past 30 years. This conclusion is reinforced by the increased number of sightings in areas near the Platte, especially in the Rainwater Basin Area to the south (Appendix J). Although the reasons for this decrease are not fully understood, the factor that appears most likely to have caused reduced use of the channel is the same as that affecting sandhill crane use of the river, i.e., changing habitat conditions brought on by reduced channel width, growth of woody vegetation on islands and channel banks, and increased human activity, particularly adjacent to roads and bridges. Other disturbance factors include the construction and use of Interstate 80 to the north, farming activities in areas which were formerly part of the river channel or adjacent wet meadows, gravel pit operations, and home construction. All of this activity along the Platte River probably has inhibited whooping crane use.

The relationship of the Platte River to whooping cranes

The importance of the Platte River to whooping cranes has been the subject of much discussion in recent years because of increased pressures for diverting much of the remaining flows from the river for various purposes. Additional diversion of flows is likely to cause further habitat degradation, thus concern has been voiced for the welfare of the whooping crane population. To address the issue adequately requires some understanding of how whooping cranes use the Platte River, including an examination of whether the Platte serves as a staging area for whooping cranes similar to that of the sandhill crane population. By staging area, reference is made to an area where migrating birds traditionally congregate and remain for a period of time in order to ready themselves physiologically for the next stage of their migration.

The whooping crane population apparently does not use the Platte River as a staging area because the cranes do not congregate there on a year-to-year basis; nor do they stay in that area for a sufficient period of time to replenish significantly or increase their lipid reserves. It is doubtful that whooping cranes ever used the Platte River as a staging area in the same manner as sandhill cranes do today. Whooping cranes migrate as individuals, pairs, families, and small flocks; they probably never congregate into large flocks in a restricted geographic area as do sandhill cranes. There is little evidence to suggest that individuals or pairs use the same area on the river from year to year. Whooping cranes rarely stay on or near the Platte for longer than 5-7 days, with overnight or two-day stops being the most common. The brief stopover interval suggests that the Platte accounts for a relatively small part of the lipid reserves deposited during spring migration. Whooping cranes probably accumulate substantial lipid reserves during spring migration but do not restrict lipid deposition to a few staging areas on the Great Plains migration route as is characteristic of sandhill cranes. The Platte River appears to best fit the description of a nontraditional stopover for whooping cranes. A nontraditional stopover area is a site which offers suitable habitat but is used on an irregular basis.

Information presented in the preceding discussion does not diminish the need to maintain habitat for whooping cranes along the Platte River. During migration, the species requires access to the types of habitat still available along some reaches of the Platte. Therefore, the river offers the potential for meeting needs of both the sandhill crane population and whooping cranes on a long-term basis. The habitat requirements of the whooping crane and sandhill crane populations for roosting and foraging appear to be similar. This is an important consideration given the rate of loss of other potential stopover sites in the region, especially in the Rainwater Basin Area, and the great importance of this site in the past.

The decreased use of the Platte River in recent times and associated rise in use of the Rainwater Basin Area by whooping cranes is a serious concern. With most of the rainwater basins destroyed, waterfowl and crane populations are confined into the relatively small habitat base that remains. As discussed in a later section, major avian disease outbreaks have occurred in recent years in south central Nebraska. Whooping cranes have been reported at several rainwater basins where large waterfowl die-offs from avian cholera have been recorded (Appendix J). Because sandhill cranes and presumably whooping cranes are susceptible to avian cholera, use of the Rainwater Basin Area as an alternative to the Platte Valley may represent a direct threat to whooping cranes. Twice in the last 6 years (spring 1975 and spring 1979) whooping cranes have been chased from wetlands experiencing avian cholera outbreaks and on one of these occasions the birds settled on the Platte. Limited use of the rainwater basins by sandhill cranes also has been recorded in recent years (Appendix K). In all likelihood, the disease problem will persist in the Rainwater Basin Area, underscoring the need to maintain adequate habitat along the Platte River which provides the species with sites that minimize exposure to avian cholera.

Bald Eagles

Impact of riverine conditions on distribution and abundance of eagles

Distribution of bald eagles on the study area changed only slightly during the 1978-79 and 1979-80 winters although the magnitude of ice-free channel habitat varied widely between years (Fig. 20). Eagles tended to concentrate in those reaches of river where availability of ice-free habitat was most stable from year to year due to discharges from reservoirs or power plants. The average percent open water ranged from 17% in January and February 1979 to 68% during this same period the following year. The 1978-79 winter was the coldest on record in Nebraska,

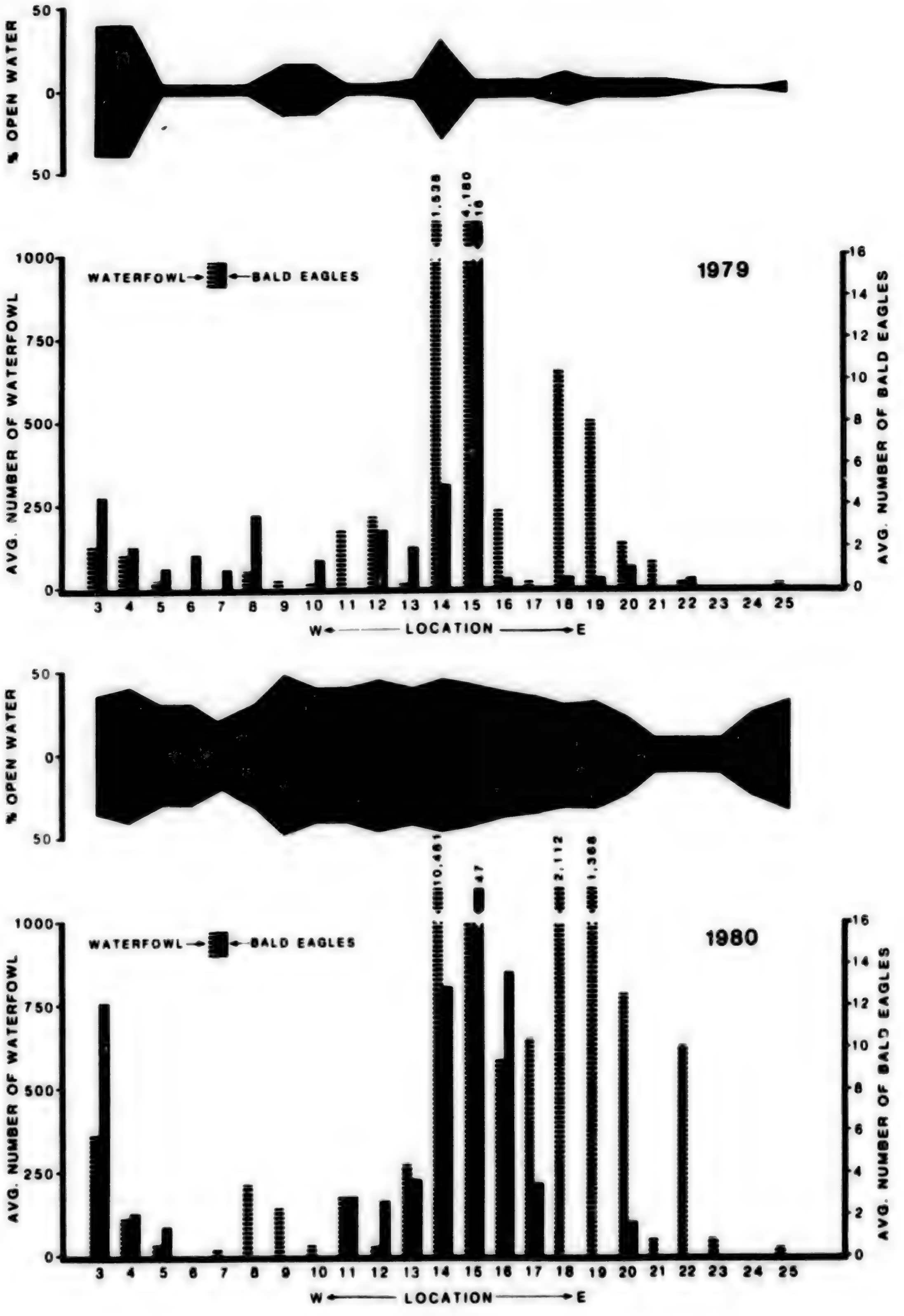

Fig. 20. Distribution of bald eagles and waterfowl during the 1978-79 and 1979-80 winters in relation to availability of open water (Locations are identified in Fig. 16).

and most of the river was frozen during that year. Ice-free areas were restricted primarily to 2.5 km (1.6 miles) of river channel downstream from Kingsley Dam, a few seepage areas, and downstream from the Tri-County Diversion Canal discharge site. Warm return flows from the canal maintained the south channel in an ice-free state for approximately 13 km (8 miles) in the Lexington-Overton Area. During the mild winter that followed (1979-80), ice-free habitat occurred in nearly every reach of the river (Fig. 20). Slush ice frequently formed in the channel but often melted by late afternoon. Ice break-up occurred by 15 March during both years.

Although the distribution of bald eagles and waterfowl was similar during both years (Fig. 20), numbers of both more than doubled in 1980. An improvement in foraging conditions appears to have been at least partially responsible for the higher use of the study area during the latter year.

Relationship of riverine conditions to food resources

The status of riverine conditions in winter had a marked influence on prey availability to eagles. Food habits data indicate that fish are a preferred item in the diet. Foraging success on fish, however, varies markedly with river conditions. Eagle success at capturing fish is enhanced by low flow conditions and by other effects of power plants, in particular, changes in currents and water temperature. Gizzard shad, a major food item of bald eagles along the Platte River, occur near the surface when water temperature exceeds 7°C and, therefore, are more vulnerable to predation. When the temperature drops below this level, shad seek greater depths in the channel, and are less available to eagles. With cold atmospheric temperatures during the 1978-79 winter, water temperature remained below 7°C and shad were not available. Substantial numbers of shad also became available to eagles after being stunned or killed by the power turbines. Greater access to fish in the south channel downstream from the Tri-County Canal discharge site during the peak water release period caused large numbers of eagles to gather in the area during the 1979-80 winter. For example, 106 eagles were counted along 8 km (5 miles) of river downstream from the canal discharge site on 21 January 1980.

When fish are not readily available, bald eagles shift to alternative prey. The shift in diet under certain conditions could increase the risk of mortality from lead poisoning in the wintering eagle population because of increased predation on mallards carrying lead shot. The extent to which mallards occur in the diet appears related to availability of certain other potential prey. During the 1979-80 winter, for example, with a general lack of snow cover, eagles preyed heavily on jackrabbits. During the previous winter heavy snow cover and limited access to fish caused increased predation on waterfowl. Although many of the ducks eaten by bald eagles were pirated from other raptors, overall mallard losses presumably are to a considerable extent attributable to eagles because other raptors continued to prey upon mallards until their needs were met.

A bald eagle living exclusively on mallards would require approximately 23 mallards per 100 days during winter to meet its dietary requirements. Projecting these data to an overwintering population of 200 eagles and assuming 37% of the diet to be mallards as suggested from egested pellet analyses, a total of 1679 mallards would be needed to meet eagle population food requirements during a 100-day winter period. These data probably are indicative of the most severe conditions to be experienced but do provide insight into the potential degree of impact on this wintering mallard population.

Perhaps most importantly, high predation rates on waterfowl increase eagle susceptibility to lead shot poisoning. The lead shot incidence rate is not known for the Platte River wintering mallard population. However, lead shot were found in nine egested eagle pellets. Most shot were associated with waterfowl remains although one shot each was obtained from remains of a pheasant and a mammal.

Specific recommendations concerning manipulation of riverine flow do not appear warranted at the present time although it is recommended that close monitoring of the wintering bald eagle population be continued.

Breeding Birds

Impact of changes in hydrology and land use on populations

Before settlement, the Platte and North Platte Valleys of Nebraska contained extensive lowland meadows interrupted only by the broad open channels of the rivers. Reduced flows, the concomittant encroachment of woody vegetation upon the channel, and the cultivation of much of the low grasslands have markedly changed the distribution and abundance of breeding bird populations.

Populations of those species associated with riparian woodland habitat in the Valleys have increased substantially during modern times as this habitat base has grown. In the mid-19th century, woodland was largely absent west of Grand Island, whereas an inventory of riparian woodland along the 203 miles of channel from Kingsley Dam to Chapman (based on August 1979 color photography at a scale of 1:8000) indicated that 21,300 ha (52,600 acres) were present. Fifty-seven species of birds were encountered on wooded islands in the channel including 35 considered to be breeding. Five species reached their maximum density on wooded channel islands (willow flycatcher, Bell's vireo, common yellowthroat, cardinal, and indigo bunting).

One species that has benefited from woody vegetation encroachment is Bell's vireo. This species is a common resident in many riparian systems of the southwestern United States and its range has been expanding slowly northward; breeding pairs are encountered regularly as far north as southwestern Wisconsin. During this study it was found only sparingly in the river systems of the sandhills, most notably in the Loup River System, where it occurs locally in limited numbers. In the Platte Valley, however, Bell's vireo is a common breeding species on river islands with woody vegetation. The breeding population was estimated at about 7000 pairs. A qualitative assessment of the impact of woody vegetation encroachment on the abundance and distribution of various other species occurring in the Platte Valley is shown in Appendix L.

Species that nest on the open sandbars of the Platte River have been affected adversely by the encroachment of woody vegetation. The most profound impact has been on the distribution and abundance of the least tern and piping plover. Both species require broad expanses of unvegetated river channel and sparsely vegetated sandbars. Research on the nesting ecology of the least tern and piping plover reflects their preference for open sites; the microhabitat within a 1-m^2 area with the nest at the center averaged 72% and 75% bare ground for least terns and piping plovers. Although both species nested exclusively on river islands, the least tern generally nested on the highest ridges. Plovers nested at lower sites (mean depth to moisture at 17 least tern nests was 26 mm and at 39 piping plover nests averaged 10 mm). Reduced flows in the Platte River have resulted in less sorting and moving of the alluvium thereby reducing the frequency at which dry unvegetated ridges occur on the islands.

Originally, least terns were widely distributed on the study area with confirmed nest records from near Lexington and at North Platte. The least tern is now restricted almost exclusively to a reach of river channel bordering Mormon and Shoemaker Islands, a distance of about 3 km (1.8 miles). In 1979, the breeding population was estimated at 30 pairs.

The largest group of species in the Valley to undergo a major population decline in recent times has been those species associated with the native meadows (low grassland). Thirty-five species were found in this habitat type during the study, including 27 that were considered breeders. The magnitude of grassland habitat loss is reflected in the present habitat composition of the three sandhill crane staging areas. Among the estimated original 790 km^2 (305 mi^2) of grassland habitat on the staging areas, approximately 240 km^2 (92 mi^2) or 30% remain.

The loss of approximately 70% of the native meadows presumably caused sharp declines in the abundance of the upland sandpiper, bobolink, eastern meadowlark, grasshopper sparrow, and other species breeding in this habitat type. Cropland, the habitat type that is rapidly replacing the native meadows, supports markedly fewer species. For example, corn, which accounts for much of the cropland acreage in the Valley, supported only three breeding species (horned lark, killdeer, and western meadowlark), an 89% decline in number of species present.

DISEASE CONCERNS

Introduction

Because migratory bird losses to disease represent a major concern associated with habitat degradation on the study area, this section of the report has been prepared to provide detailed background information on the disease problem.

Four diseases with epizootic potential have been reported in migratory birds within the Platte River Study Area or in migratory bird populations which utilize the area. Botulism, originally known as western duck sickness, was reported in waterfowl in Nebraska before 1932 (Kalmbach and Gunderson 1934), and Nebraska ranks seventh among the western states and Canadian provinces in waterfowl losses to this disease (Rosen 1971a). In early 1973, an outbreak of duck plague, or duck virus enteritis, occurred in mallards and Canada geese at the Lake Andes National Wildlife Refuge and on the nearby Missouri River 274 km (170 miles) north of Grand Island, just across the Nebraska border in South Dakota (Berlinger et al. 1973). An outbreak of aspergillosis killed an estimated 1000-1500 crows in south central Nebraska in the fall of 1974 (Zinkl et al. 1977a), and avian cholera was confirmed in migratory waterfowl and crows in the Rainwater Basin in the spring of 1975 (Zinkl et al. 1977b). Botulism, duck plague, and avian cholera are discussed separately. Aspergillosis, although reported in migratory bird populations on the study area, is less likely to become a significant threat to waterfowl and crane populations as a result of habitat degradation problems described in this report and is not addressed in the following discussion.

Botulism

Botulism is a food poisoning caused by the ingestion of the toxin produced by the bacterium *Clostridium botulinum*. Most species of waterfowl and shorebirds are susceptible to type C botulinal toxin, but the incidence of the disease may be influenced by the food habits of the individual species and their occurrence on the outbreak area (Rosen 1971a). Summer outbreaks typically involve dabbling ducks and shorebirds. Although Canada geese are susceptible to the toxin, they usually are not present where botulism occurs during the summer, and when they do arrive, their feeding habits reduce the likelihood of their encountering the toxin (Jensen and Williams 1964). However, an outbreak of botulism at the Horicon National Wildlife Refuge in Wisconsin in 1978 did involve Canada geese. Raptors are more resistant to type C botulinal toxin and the disease has not been reported in sandhill or whooping cranes.

The basic epizootiology of waterfowl and shorebird botulism is relatively simple although the complete chain of events leading to a botulism outbreak may be complex. The "microenvironment concept" is now generally accepted by waterfowl botulism investigators. The concept suggests that *C. botulinum* type C produces toxin in small, discrete, particulate food items, such as invertebrate carcasses, which provide the anaerobic conditions and nutrient requirements for growth of the bacterium independent of the surrounding wetland environment, and protect the toxin from dilution or inactivation (Bell et al. 1955; Enright

1971). Temperature requirements are readily met during warm summer days. This theory is supported by laboratory evidence of toxin production in aquatic and terrestrial invertebrate carcasses. Protection of toxin in particulate food items such as invertebrate carcasses, and preservation over winter by freezing also appear to be the most plausible explanations for spring outbreaks which sometimes occur before water temperatures have reached a point favorable for the growth of *C. botulinum* (Pearson and Jensen 1972).

Water conditions including water level, salinity, dissolved oxygen, available nutrients, toxic substances and other factors influence the amount of decaying animal protein available for the growth of *C. botulinum* (Pearson and Jensen 1972). Declining water levels and increased water temperature or salinity may cause marginal conditions for the survival of previously thriving invertebrate populations, or invertebrates may become stranded on mud flats used by waterfowl and shorebirds. Conversely, rising water levels may drown terrestrial invertebrates creating conditions conducive to toxin production, or may flood vegetation, causing a release of nutrients and stimulating the growth of aquatic invertebrate populations to unstable levels. In either circumstance, the collapse of these populations makes available large quantities of decaying animal protein particles for toxin production. Influxes of agricultural nutrients also may disrupt the nutrient budget of wetlands, thereby stimulating the growth of certain invertebrate populations, or algal blooms which lead to oxygen depletion followed by aquatic invertebrate or vertebrate mortality. The introduction of insecticides may cause direct mortality of invertebrates, whereas the application of herbicides can disrupt aquatic food chains by the sudden depression of phytoplankton production.

Although information is inadequate to evaluate thoroughly the impacts of changing conditions on the study area in relation to occurrence of botulism outbreaks, sufficient information is available to warrant discussion of the issue. Impacts of botulism on migratory bird populations are most likely to involve local breeding populations, and possibly early fall migrants, although spring migrants may also be exposed to botulinal toxin. Toxin produced during summer outbreaks can be preserved over winter in frozen invertebrate carcasses which can become available the following spring when large numbers of migrant waterfowl are using the area. Ducks periodically are affected in such spring outbreaks in South Dakota (Pearson, pers. comm.) and geese could also be expected to become involved if spring botulism outbreaks were to occur on wetlands in the Rainwater Basin Area. The potential threat from botulism is less severe than from other diseases which will be discussed later because sandhill and whooping cranes and most of the ducks and geese utilize the study area during the spring and then migrate on to other areas.

Whether or not sandhill or whooping cranes would be subjected to an increased risk of botulism would depend largely upon the specific sources of toxin in the outbreak, the occurrence of cranes on the outbreak area, and the specific food habits of the cranes. Whooping cranes utilize the Rainwater Basin wetlands and to a lesser extent the Platte River during their spring migration, and feed on aquatic and terrestrial invertebrates (see Whooping Crane Feeding Ecology section). It is not known if they feed on dead invertebrates, or on live invertebrates such as blowfly larvae which can accumulate toxin. Ingestion of these foods would markedly increase their risk of exposure to botulinal toxin. It is known that whooping cranes feed on fish, and Jensen et al. (1968) have shown that live fish consuming type C botulinal toxin can convey lethal doses of toxin when eaten by birds. If deteriorating habitat conditions on the Platte River result in significant numbers of sandhill cranes relocating to wetlands in the Rainwater Basin Area, sandhill cranes also could become affected by botulism outbreaks.

Certain man-induced changes in the environment of the study area have increased the likelihood of botulism outbreaks. Surface water drainage and lowering of groundwater levels associated with agricultural development already have severely altered or eliminated most of the natural wetlands in the Rainwater Basin Area. Further disruption from agricultural chemicals, drastic fluctuations in water levels, and nutrient enrichment in the remaining wetlands can be expected to increase the probability of botulism outbreaks by increasing the availability of decaying animal protein media for toxin production. Under these conditions, the occurrence and the magnitude of outbreaks becomes a function of the presence of susceptible birds. Concurrently, as wetlands continue to be lost, birds will tend to relocate on those which remain. Consequently, larger increments of the bird population are placed at risk when botulism outbreaks occur, and the probability of outbreaks also increases. Wells and associated facilities on 12 waterfowl production areas allow water to be pumped from underground aquifers. These wells allow some control over botulism outbreaks by stabilizing water conditions on wetlands.

Duck Plague

Duck plague is an acute, highly contagious herpes virus disease of ducks, geese, and swans (Leibovitz 1971). The 1973 duck plague outbreak at the Lake Andes National Wildlife Refuge in south central South Dakota killed an estimated 40% of 100,000 mallards and 3% of 9000 Canada geese wintering on the refuge and nearby Missouri River (Berlinger et al. 1973). The outbreak was the first major epizootic of this disease reported in free-flying wild waterfowl in the world (Proctor et al. 1975), although it had occurred in domestic ducks in Europe as early as 1923 and had been diagnosed in commercial duck flocks on Long Island, New York, in 1968 (Leibovitz 1971).

Evidence indicates that survivors of the disease may become chronically infected carriers which may perpetuate the virus within waterfowl populations and serve as the source for new outbreaks (Burgess et al. 1978). Banding data show that more than 10% of the mallards banded during the winter at Lake Andes between 1963 and 1969 were recovered in eastern Nebraska (Kuck 1971). Although it is probable that most of the survivors of the 1973 Lake Andes outbreak have by now been lost by attrition, it is evident that a potential does exist for the introduction of duck plague into waterfowl populations using the study area, just as it existed at Lake Andes.

The lack of additional reported epizootics of duck plague in free-flying waterfowl since the 1973 Lake Andes outbreak has prevented identification of the specific factors responsible for the occurrence of such outbreaks, other than the presence of the virus and susceptible waterfowl. The density of birds presumably was a contributing factor in the transmission of the virus when duck plague reached epizootic levels in waterfowl utilizing the limited area of open water in Owens Bay on the Lake Andes National Wildlife Refuge in 1973. However, substantially higher numbers of waterfowl had occurred on the area in previous years with no evidence of the disease (Berlinger et al. 1973), suggesting that the virus was not introduced until 1973, or that other unrecognized factors were responsible for triggering the outbreak. Until more definitive information is available on the epizootiology of duck plague in free-flying wildfowl it should be assumed that high numbers of waterfowl on limited water area, such as existed at Lake Andes in 1973, increases the potential for duck plague outbreaks.

Alteration of wetlands and diminished flows in the Platte are causing densities of both waterfowl and cranes to rise. High densities of waterfowl already occur on the study area during the spring migration, and continuing wetland destruction in the rainwater basins is further increasing densities of waterfowl on the remaining wetland areas. Similarly, reductions of flows in the Platte River effectively increase the density of birds per acre foot of water, even if their numbers and distribution are not affected.

It is important that adequate flows be maintained in the Platte during spring migration to disperse cranes and waterfowl and to reduce the potential for disease outbreaks, particularly if large numbers of birds are forced to move to the River. When duck plague occurred at Lake Andes in the winter of 1973, it was considered essential to avoid dispersing the infected birds to areas where other populations would be exposed, but also to implement a control program which would terminate the outbreak before the arrival of additional migrants. The control program sought to move the birds from the limited open water area of the Lake Andes National Wildlife Refuge to the Missouri River 7 miles away where releases of up to 565 m^3/sec from the Fort Randall Dam created an extensive open water area for dispersal of the waterfowl and a high rate of flow for dilution of the virus, both of which contributed to a marked reduction in the density of birds per unit volume of water (Berlinger et al., unpubl. report).

Under present conditions, if duck plague were to occur in waterfowl within the Rainwater Basin Area, the Platte River would provide a possible area for dispersal of the birds and flows for dilution of the virus. Duck plague virus affects only waterfowl, thus such a control program would present no danger to cranes, eagles, or other species of wildlife (although the possible exposure of domestic waterfowl must be considered). If flows in the Platte River were to diminish, however, this option for disease control might be precluded.

Avian Cholera

Avian cholera, an infectious disease caused by the bacterium *Pasteurella multocida*, has been reported in a wide variety of domestic and wild birds (Rosen 1971b; Heddleston 1972). Outbreaks in wild birds have most frequently been reported in waterfowl (Rosen 1971b), but avian cholera also has been reported in the bald eagle (Rosen 1972) and other raptors (Rosen and Morse 1959; Hunter 1967; Rosen 1971b). Ten sandhill cranes out of a wintering population of 5600 died in a 1970-71 avian cholera outbreak in California (Rosen 1972). Individual sandhill cranes have died of avian cholera in Nebraska at the National Audubon Society Lillian Annette Rowe Bird Sanctuary on the Platte River in the spring of 1975 (James Hurt, pers. comm.), and on a Rainwater Basin wetland in the spring of 1977 (Chris Brandt, pers. comm.). Avian cholera has not been diagnosed in whooping cranes, but the wide host range of *P. multocida* in birds indicates that whooping cranes must be presumed to be susceptible to the disease (Zinkl et al. 1977b).

In migratory birds, avian cholera typically is an extremely acute disease, with few signs other than dead birds being evident (Jensen and Williams 1964; Rosen 1971b). Few sick birds usually are seen and they frequently die shortly after signs appear (Rosen and Bischoff 1949; Jensen and Williams 1964; Rosen 1971b; Zinkl et al. 1977b). Occasionally, waterfowl displaying disturbances of equilibrium and other neurological signs may be seen as outbreaks progress (Rosen and Bischoff 1949; Jensen and Williams 1964; McDougle et al. 1965; Vaught et al. 1967; Rosen 1971b; Zinkl et al. 1977b). In crows, however, avian cholera may occur in a chronic form (Zinkl et al. 1977b). Healthy, chronically infected *P. multocida* carriers occur in domestic poultry and are believed to be important in maintaining the infection and serving as the source of new outbreaks (Heddleston 1972). Chronically infected carriers may also occur in survivors of avian cholera outbreaks in migratory birds (Jensen and Williams 1964; Vaught et al. 1967; Donahue and Olson 1969; Rosen 1971b), and Korschgen et al. (1978) found a low incidence of *P. multocida* carriers in common eiders.

Dissemination of *P. multocida* among birds occurs via nasal exudates which contaminates the environment, especially food and water (Rosen 1971b; Heddleston 1972); feces are a much less significant source of contamination (Heddleston 1972). The nasal exudate of diseased birds contains large numbers of *P. multocida* (Rosen 1971b; Heddleston 1972) and copious quantities of this material may drain from the bills of birds immediately upon death (Rosen 1971b). *P. multocida* may survive for 2 months in carcasses at refrigerator temperatures and over 100 days in moist soil at 3°C (Heddleston 1972). A pond in California was found to remain infective for 3 weeks after the last carcasses of avian cholera victims had been removed (Rosen 1969).

The most common routes of infection for *P. multocida* in birds probably are by ingestion or inhalation, with the organism gaining access through the mucous membranes of the mouth, pharynx, and upper air passages (Heddleston 1972). Infection also may occur via the eye (Heddleston 1972). Contaminated water, therefore, is thought to be an important source of infection, especially for waterfowl (Rosen 1971b) but contaminated food also may be a source (Rosen 1971b; Heddleston 1972).

Control of avian cholera through the use of antibiotics, chemotherapy, and vaccination, although effective in domestic poultry (Heddleston 1972), has had little application in dealing with the disease in migratory birds (Jensen and Williams 1964). Consequently, the available control measures generally are limited to practices aimed at reducing the level of transmission of the infection within and among migratory bird flocks. These practices typically include collection and disposal of carcasses and discouraging bird use of heavily contaminated areas by draining ponds or chasing the birds to other areas (Rosen and Bischoff 1949; Jensen and Williams 1964; Vaught et al. 1967; Rosen 1971b; Zinkl et al. 1977b). Killing of infected flocks may be feasible under some circumstances where dispersal of the birds can be avoided (Rosen 1971b; Pursglove et al. 1976). Dispersal of migratory birds as an avian cholera control measure must be carefully evaluated on a case-by-case basis and, unless the movements of the infected birds can be predicted with a high degree of certainty, carries the risk of spreading the disease to other populations (Jensen and Williams 1964; Rosen 1971b). Measures to avoid the mixing of birds from different flocks are an important aspect of avian cholera prevention (Heddleston 1972).

The first confirmation of avian cholera in migratory birds in Nebraska occurred in waterfowl and crows in the Rainwater Basin Area in 1975 (Zinkl et al. 1977b); however, waterfowl with field signs suggestive of avian cholera were observed on the Platte River near Overton, Nebraska, during the springs of 1950 and 1964 (McDougle et al. 1965). An estimated 20,000-25,000 waterfowl died in the 1975 outbreak in the Rainwater Basin Area (Zinkl et al. 1977b), 7500-8500 were estimated to have died in the spring of 1976, and 7500-10,000 in the spring of 1977.

Losses in the Rainwater Basin Area were low in the spring of 1978, but 3100 birds, primarily coots, died of avian cholera on Lake McConaughy and at the Swanson Reservoir in Hitchcock County (Hurt 1978). Losses were low again in 1979, but in the spring of 1980, avian cholera occurred on at least 50 wetlands in the Rainwater Basin Area, with 30,677 dead birds collected (A. Trout, unpubl. data). Sites of heavy waterfowl mortality and their distribution in relation to sandhill crane staging areas 1 and 2 are shown in Fig. 21. The principal species of waterfowl lost during the avian cholera outbreak in 1980 and numbers found are as follows: mallards, 9351; pintails, 8045; white-fronted geese, 6574; Canada geese, 2787; American wigeon, 1121; and redhead, 1114.

Although waterfowl mortalities in the 1975 Nebraska outbreak seemed to occur in proportion to the abundance of each species present (Zinkl et al. 1977b), differences in species susceptibility have been reported in other outbreaks (Rosen 1971b). Coots generally are reported to be highly susceptible to avian cholera and frequently are the first birds observed to die in outbreaks (Rosen and Bischoff 1949, 1950; Rosen and Morse 1959; Rosen 1969; Pursglove et al. 1976). Gulls are susceptible but appear to survive longer and may contribute to the local spread of the disease (Rosen and Bischoff 1949, 1950; Rosen and Morse 1959; Rosen

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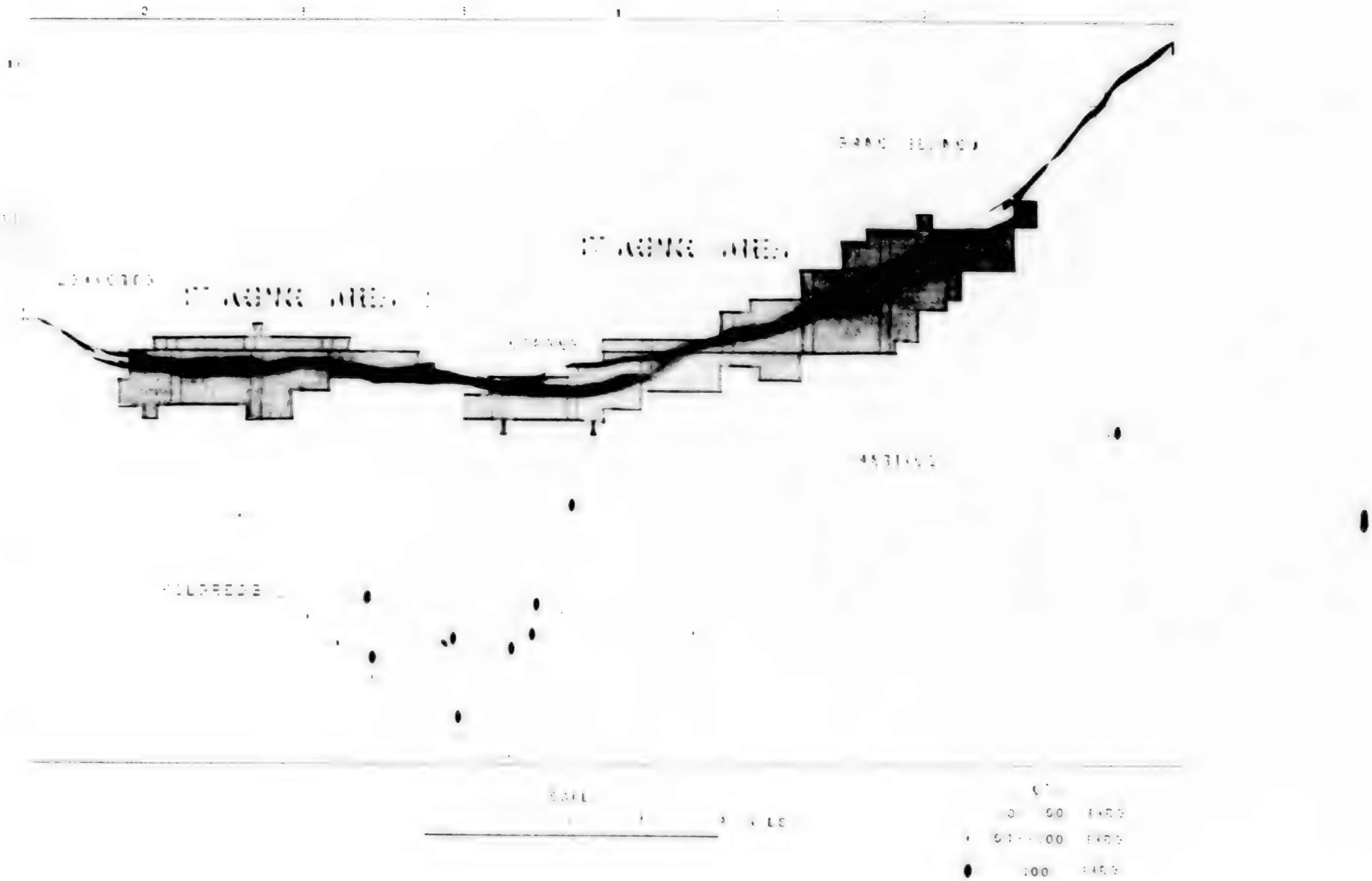
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1971b). Petrides and Bryant (1951) noted during a 1949-50 avian cholera outbreak in Texas that the relationship between the abundance of waterfowl species and their mortality was not direct, and that 16 times more green-winged teal, but only half as many geese, died as than was expected, based upon their total numbers. Northern shovelers, American wigeons, canvasbacks, teal, and pintails were observed to be the most susceptible waterfowl, and mallards the least susceptible in the 1948-49 California outbreak (Rosen and Bischoff 1949). Rosen (1969) analyzed avian cholera mortalities in California waterfowl and found that in diminishing order of susceptibility the species were wigeon, shoveler, mallard, and pintail. He also found that white-fronted geese were more susceptible than snow geese or Canada geese, and that all three species of geese were more susceptible than mallards (Rosen 1969). Although differential species susceptibility to avian cholera occurs in domestic poultry (Heddleston 1972), differential mortality rates in migratory birds may be a reflection of relative exposure based upon different feeding habits and the utilization of different subhabitats, rather than differential resistance to the disease (Rosen and Bischoff 1949; Rosen 1969, 1971b).

Despite the long history and frequent occurrence of avian cholera in migratory birds, no comprehensive epizootiologic studies have been reported of the disease in wild bird populations and little objective information is available on the conditions which contribute to outbreaks (Jensen and Williams 1964; Rosen 1971b). In domestic poultry, withdrawal of feed and water, abrupt changes of diet, and environmental stress are reported to increase the incidence of avian cholera (Heddleston 1972). No correlation, however, was found between temperature and the mortality rate in the 1949-50 Texas outbreak in migratory waterfowl, although an apparent correlation was noted with wind (Petrides and Bryant 1951), and Bennett and Bolen (1978) found a correlation between wind velocity, relative humidity, and a stress response in wintering green-winged teal in Texas. The 1970 outbreak on Chesapeake Bay was preceded by several weeks of extremely cold weather (Locke et al. 1970). The 1964 outbreak at the Squaw Creek National Wildlife Refuge was associated with cold temperatures, a corn diet, and lead poisoning in mallards (McDougle et al. 1965). The 1975 Nebraska outbreak was preceded by a brief snow storm (Zinkl et al. 1977). However, no cause and effect relationship has been demonstrated between any of the aforementioned factors and the occurrence of avian cholera.

Nutrition has been suggested as an important factor in avian cholera (Rosen and Bischoff 1950), and outbreaks in common eiders occur during the nesting season when female eiders may lose up to 50% of their body weight (Korschgen et al. 1978). Avian cholera apparently also occurs in snow geese on their Canadian nesting grounds when females undergo weight loss during laying and incubation. However, diet had no apparent influence in the 1949-50 outbreak in waterfowl in Texas (Petrides and Bryant 1951) and, in fact, waterfowl dying in avian cholera outbreaks frequently are in excellent condition with abundant fat deposits (Quortrup et al. 1946; McDougle et al. 1965; Vaught et al. 1967; Locke et al. 1970; Zinkl et al. 1977; Wobeser et al. 1979). Rosen (1971b) postulated that the improving physical condition of waterfowl in spring as they are preparing to migrate to northern nesting grounds might be an important factor in preventing winter avian cholera outbreaks in California. However, the persistence of avian cholera within waterfowl undergoing rapid fat deposition on the spring staging area in Nebraska would appear to discount this hypothesis.

No consistent correlation exists between the total numbers of birds present and the total mortality in avian cholera outbreaks in migratory birds (Rosen 1969, 1971b). Apparently the severity of outbreaks is influenced by factors other than population size. However, high bird densities are presumed to facilitate the transmission of contagious diseases (Rosen and Bischoff 1950; Jensen and Williams 1964), and overcrowding and "concentration" frequently are cited as factors associated with avian cholera outbreaks in migratory waterfowl (Rosen and Bischoff 1950; Petrides and Bryant 1951; Klukas and Locke 1969). The 1970 outbreak on Chesapeake Bay occurred when sea ducks concentrated on shallow portions of the bay after cold weather (Locke et al. 1970). The maintenance of open water by pumping at the Squaw Creek National Wildlife Refuge concentrated an estimated 300,000 waterfowl on small water areas and was thought to be an important factor in the 1964 outbreak (McDougle et al. 1965; Vaught et al. 1967). Late fall flooding followed by winter drought, which resulted in a decrease in the number and size of water areas and the concentration of waterfowl, was associated with the loss of an estimated 37,000 waterfowl in California in 1970-71 (Rosen 1972). High bird densities were cited as a factor in avian cholera outbreaks among nesting common eiders (Korschgen et al. 1978). Low water conditions and spring storms which delayed migration were cited as factors which may have concentrated waterfowl in Nebraska during the spring of 1975, contributing to an outbreak of avian cholera (Zinkl et al. 1977). However, Rosen (1969) explains that, "... population density is considered important in the transmission of disease per se, but another factor is not the total population of the waterfowl or of any one species, but rather how locally concentrated they are." However, studies relating actual bird densities to either total mortality or mortality rate in migratory waterfowl have not been reported, so the relationship remains unconfirmed.

Estimated waterfowl numbers, densities, total mortalities, and crude mortality rates for the 1980 spring avian cholera outbreak in the Rainwater Basin Area show no consistent patterns between either total waterfowl numbers or densities and either total mortality or crude mortality rate (Table 11). However, these population estimates are based upon numbers present on a single day and, therefore, are not indicative of total waterfowl use on these wetlands during the outbreak, or even the highest numbers present, so crude mortality rates may substantially overestimate the actual mortality rates. The total mortality counts also were cumulative and, along with the mortality rates, would be more meaningful if related to waterfowl use days.

Another major deficiency in understanding the epizootiology of avian cholera in migratory birds is the absence of information relating the occurrence and magnitude of outbreaks to the immune status of the populations involved. The pattern of the recent avian cholera mortalities in migratory waterfowl in Nebraska (an initial severe outbreak in 1975

Table 11. Avian cholera mortalities among waterfowl in certain wetlands of the Rainwater Basin Area during spring 1980 in relation to population size, water area, and density of birds.

Basin	Total waterfowl numbers[a]	Water area[b] (in hectares)	Density (birds/ hectare)	Total mortality	% crude mortality rate[c]
Prairie Dog	77,000	153	501	4780	6.2
Gleason	110,000	343	321	4291	3.9
Clark	26,000	138	188	3426	13.2
Harvard	106,200	277	383	1568	1.5

[a] 15 March 1980 population estimate.

[b] 18 March 1980 water hectarage estimate.

[c] Total mortality divided by 15 March population estimate.

with 20,000-25,000 deaths, followed by 2 years of reduced losses, 2 more years of low losses, and then another large outbreak in 1980 with 30,677 dead birds collected) is typical of what would be expected with the introduction of a contagious pathogen into a susceptible population. High losses would be expected in the first outbreak, because few individuals would be immune. Losses in subsequent outbreaks would continue at moderate levels until a substantial portion of the population had been exposed, followed by a decline in mortality to a very low level. As the immunity level of the population waned, or as recruitment replaced the immune birds, a susceptible population would again be created, and carriers within the population might then initiate another large outbreak. The 5-year interval between the serious outbreaks in 1975 and 1980 is compatible with the fluctuating immune status which would be expected in a migratory waterfowl population. Fluctuating levels of immunity within migratory bird populations might explain the difficulty of demonstrating consistent relationships between environmental factors and outbreaks, the variations in mortalities from year to year independent of total bird numbers, and variations in mortality rates within species during different outbreaks.

Until the combined relationships of environmental stresses, bird density, subhabitat utilization, and immunity to avian cholera in migratory birds are better understood, an assessment of the impacts of changing habitat conditions on the occurrence and magnitude of outbreaks will necessarily remain conjectural. Nevertheless, certain conclusions regarding avian cholera in migratory birds on the Platte River Study Area are warranted.

It is evident that avian cholera is now established within the migratory waterfowl and crow populations which utilize the study area. Experience with avian cholera in migratory waterfowl in Texas and California (Jensen and Williams 1964; Rosen 1971b), off the coast of Maine (Korschgen et al. 1978), and in the Chesapeake Bay area (Locke et al. 1970; Pursglove et al. 1976) indicates that after a pattern of outbreaks has been established, the disease can be expected to recur. Avian cholera has now occurred in migratory waterfowl and coots in Nebraska in each of the last 6 years.

It can also be assumed that all species of birds within the study area are susceptible to avian cholera including sandhill and whooping cranes, bald eagles, and other raptors (Rosen 1971b; Zinkl et al. 1977b). Exposure will vary among species and be dependent upon their occurrence on outbreak areas, the specific subhabitats occupied, food habits, and level of association with and exposure to infected birds.

With avian cholera established in migratory bird populations utilizing the study area, it can be assumed that habitat changes which would increase the densities of birds or the level of association between flocks and species of birds, or both, will magnify losses or the occurrence of the disease, or both, in different species. Although high bird densities per se do not cause disease outbreaks, high densities may facilitate transmission of contagious pathogens when suitable environmental conditions exist. If shrinkage of the wetland habitat base in the Rainwater Basin Area continues, it will very likely increase the densities of waterfowl on remaining wetlands and increase the potential for transmission during avian cholera outbreaks. Wetland habitat destruction in the Rainwater Basin Area also can be expected to increase the level of association between waterfowl and other species of migratory birds, e.g. whooping cranes, increasing their exposure to avian cholera. If loss of Rainwater Basin wetlands results in major shifts of the waterfowl population to the Platte River, this shift would increase the level of association with the sandhill crane population and increase its exposure to avian cholera. With inadequate flows in the Platte, the potential for high losses would exist on the River.

Loss of approximately two-thirds of the river channel as roosting habitat for sandhill cranes has resulted in high densities of birds on the remaining suitable areas (Fig. 7). Dilution and dispersal of the bacterium varies directly with volume of water passing through the channel, consequently, reduced flows significantly affect exposure even when numbers and distribution of birds do not change. Should continued loss and deterioration of habitat on the Platte River result in the sandhill cranes shifting to the Rainwater Basin Area, their level of association with waterfowl would increase as would their vulnerability to avian cholera.

Whooping crane use of the Rainwater Basin Area has increased in recent years concomittant with a decline in usage of the Platte River as described in a previous section. An indication of the potential hazard was shown in 1975 when nine whooping cranes congregated on a wetland within the epizootic area during the first confirmed avian cholera outbreak on the study area (Zinkl et al. 1977b). In the latter situation, weather prevented the chasing of the cranes from the area to the Platte River until the next day (Zinkl et al. 1977b). If avian cholera were transmitted to sandhill cranes within the Rainwater Basin Area, the risk of exposure of the whooping cranes would increase substantially due to the frequent association of these species on staging areas.

If a reduction in the acreage of harvested corn and other grains occurs, it can be expected to cause increased bird densities and more frequent association of different species on upland feeding sites and wetlands where food is most plentiful. Although water appears to be a major vehicle for transmission of avian cholera in waterfowl (Rosen 1971b), transmission may also occur by contaminated food (Rosen 1971b; Heddleston 1972). Contaminated food could become an important source of infection, especially if large numbers of infected waterfowl were to feed in fields being utilized by sandhill or whooping cranes.

In summary, habitat deterioration along the Platte River, if allowed to proceed, is likely to cause the sandhill crane population to abandon the present staging areas. A shift to wetlands in the Rainwater Basin Area where avian cholera outbreaks have become common in waterfowl could follow. A similar shift appears already to have occurred among whooping cranes and knowledge that sandhill cranes readily occupy similar habitat elsewhere along their migration route, plus evidence that some sandhill crane usage of Basin wetlands has occurred in recent years (Appendix K), adds to the plausibility of this scenario being realized. A serious threat could exist for both cranes and waterfowl if habitat conditions along the Platte deteriorate and flows during spring are reduced until slackwater conditions develop. With the combination of high population densities and high levels of association between populations in a non-flowing channel environment, avian cholera outbreaks likely would involve virtually all species, i.e. waterfowl, cranes, and eagles, with little prospect for control and with mortalities being limited only by the natural course of the epizootic.

P. multocida transmission may be preventable if there is sufficient water in the Platte River to assure a high rate of flushing and dilution and a low density of birds per acre-foot. One alternative is to move the migrant waterfowl from the Rainwater Basin to the river in order to reduce the potential for occurrence of avian cholera losses. However, such management steps should be applied only after research has clearly identified movement patterns of waterfowl within the Basin Area under various habitat conditions to ensure that more serious problems are not created by inadvertently causing infected birds to disperse to disease-free sites. Maintaining adequate flows in the Platte to meet needs of cranes and waterfowl may represent the only viable prospect for controlling migratory bird losses to avian cholera within the study area.

DEVELOPMENT OF WOODY VEGETATION

Background

Until about 12,000 years ago, boreal spruce forests extended from the eastern United States to the foothills of the Rocky Mountains and dominated the vegetation of the Great Plains (Wright 1970). During this time, however, much of the Nebraska sandhills remained treeless because the Tertiary alluvium in that area was unconsolidated and strong northern periglacial winds created a system of transverse dunes (Rand 1973). A climatic warming trend in the post-Wisconsin period resulted in the demise of the boreal forest, the establishment of widespread grasslands on the western plains, and the development of deciduous forests in the eastern United States.

There has been considerable speculation about the factors responsible for the lack of trees on the midwestern plains (Borchert 1950; Bryson 1966; Wells 1970). Wells (1970) has suggested that fires which swept unhindered for miles across the prairie, and the arid climate in the plains, have both played important roles in limiting the advance of eastern deciduous forest species into the prairie biome. Fluctuations in the post-pleistocene climate have resulted in wetter periods favoring forest advancement and drier periods favoring grassland dominance. According to Rand (1973), the present climatic period favors grasslands and has remained in effect during the past 900 years. Initial expansion of eastern forests into the plains occurred along the major river courses during more mesic climatic periods when winter rainfall was greater (Kellogg 1905; Gleason 1922). In post-settlement times, the decrease in the frequency and severity of prairie fires and an increase in controlled grazing, encouraged forest development (Bessey 1899).

In Nebraska, the advancement of forests along major river systems such as the Platte was generally confined to a narrow strip along the river channel because the shifting streambed and high scouring action of uncontrolled flows inhibited forest invasion on the wide alluvial bottomlands (Kellogg 1905; Gleason 1922). Kellogg (1905) noted that over long stretches of the Platte timber growth was either "wholly absent" or consisted only of scattered cottonwood and willow. Red cedar was also present in localized areas of floodplain, but this species was most abundant along bluffs in western Nebraska.

According to Kellogg (1905) the range of red cedar expanded along the Platte from the foothills of the Rocky Mountains towards the east at the same time that deciduous forest species were expanding westward. He noted that, although cottonwood and willow were the dominant deciduous species in the advancing forest, other eastern species such as American elm, green ash, hackberry, and box elder were also present, but were generally minor components of the vegetation and their numbers progressively declined towards the West. Along with problems in establishment, much of the forest advance was hindered by the cutting of cottonwood for use in railroad and bridge building, and the cutting of red cedar for fence posts.

Since 1909, climatic conditions in central and western Nebraska have remained fairly uniform, but peak and mean annual discharge in the

Platte and North Platte Rivers have decreased significantly (Williams 1978). In many instances, declines in peak and mean annual discharge correspond to the development of the following reservoirs in Wyoming: Pathfinder, 1909; Guernsey, 1927; Alcova, 1938; Seminoe, 1939; Glendo, 1957; and Lake McConaughy in Nebraska, 1941 (Williams 1978). These reductions in discharge have decreased scouring and shifting of the alluvium on the streambed and have allowed extensive forest development on the floodplain since 1930 (Frith 1974).

Although the expansion of deciduous forest species (i.e., cottonwood, green ash, American elm, diamond willow) from the east and red cedar from the west provided a substantial number of seeds for forest development on the Platte River floodplain, planted tree claims also served as important seed sources and provided seeds from a greater variety of species. The Timber Culture Act of 1873 encouraged the planting of such tree claims, because homesteaders who planted 40 acres of trees were entitled to an additional quarter section of land (Bose 1977). Virtually all the arboreal species which established on the Platte River floodplain, including cottonwood, red cedar, Russian olive, green ash, slippery elm, American elm, red mulberry, box elder, silver maple, hackberry, and Siberian elm, were planted in tree claims (Albertson and Weaver 1945; Read 1958). Cottonwood, green ash, box elder, silver maple, American elm, and slippery elm all have airborne seeds which were easily carried to the river channel, whereas birds were probably responsible for the transport of red cedar, Russian olive, and red mulberry seeds to the floodplain (Kellogg 1905; Albertson and Weaver 1945; McVaugh 1957). Sandbar willow, indigo bush, rough-leaf dogwood, and red-osier dogwood, the dominant shrubs on the Platte River floodplain, probably developed from seed sources brought during the expansion of eastern deciduous forest to the West, whereas the range of buffaloberry and skunk bush, species which are only occasionally encountered, probably expanded eastward from the foothills of the Rocky Mountains (Kellogg 1905). Twelve major vegetation types have been delineated for the Platte River floodplain (Fig. 22). A more detailed summary of the vegetation types on the floodplain is given in Appendix M. Average percentage cover values for the principal species in each type are provided in Appendix N.

Because of the significant negative impact of woody vegetation on use of the river channel by sandhill and whooping cranes, studies were undertaken to determine forest age structure and period of forest development on the Platte River floodplain and to identify factors conducive to establishment of woody vegetation.

Depletion of Annual Flows and Channel Shrinkage

Mean annual discharges and associated change of channel widths for the North Platte River in western Nebraska and the Platte River in south central Nebraska are presented in Figs. 23 and 24. All available data on discharge rates for the period from 1910 to 1979 have been plotted.

Although, on the average, mean discharge in the North Platte River (42.63 m^3/sec) was considerably less than in the Platte River (56.28

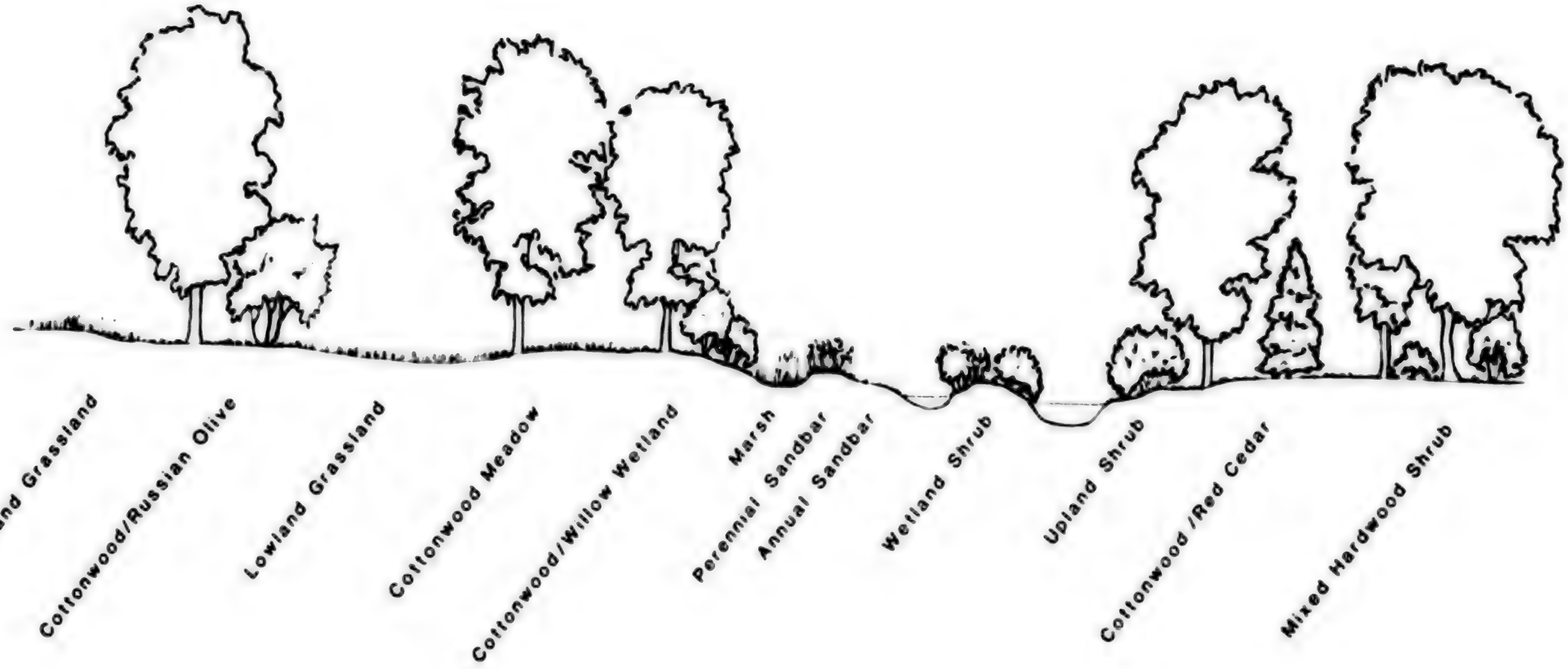
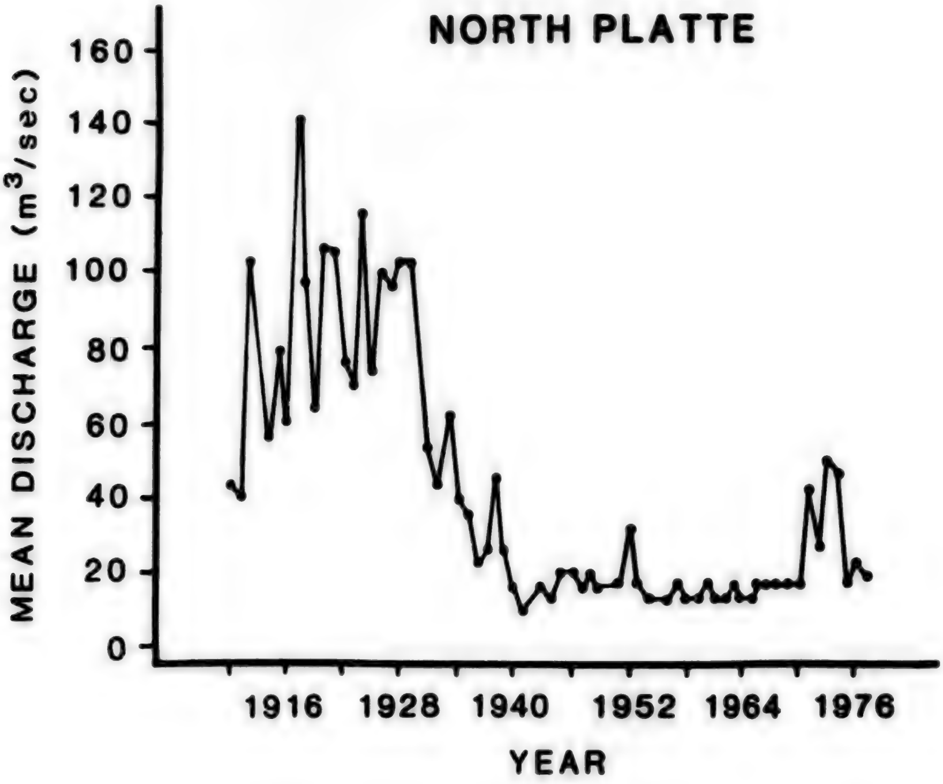


Fig. 22. The major vegetation types on the Platte River floodplain.



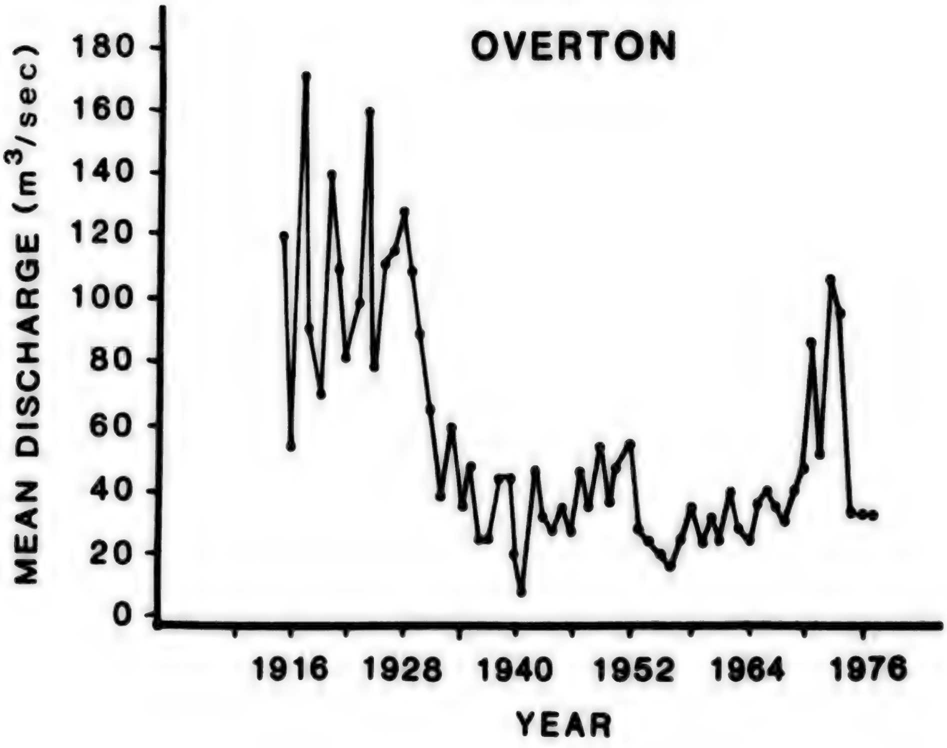


Fig. 23. Mean annual discharge along the North Platte and Platte Rivers (North Platte and Overton substations) during 1910-77 period (After Williams 1978).

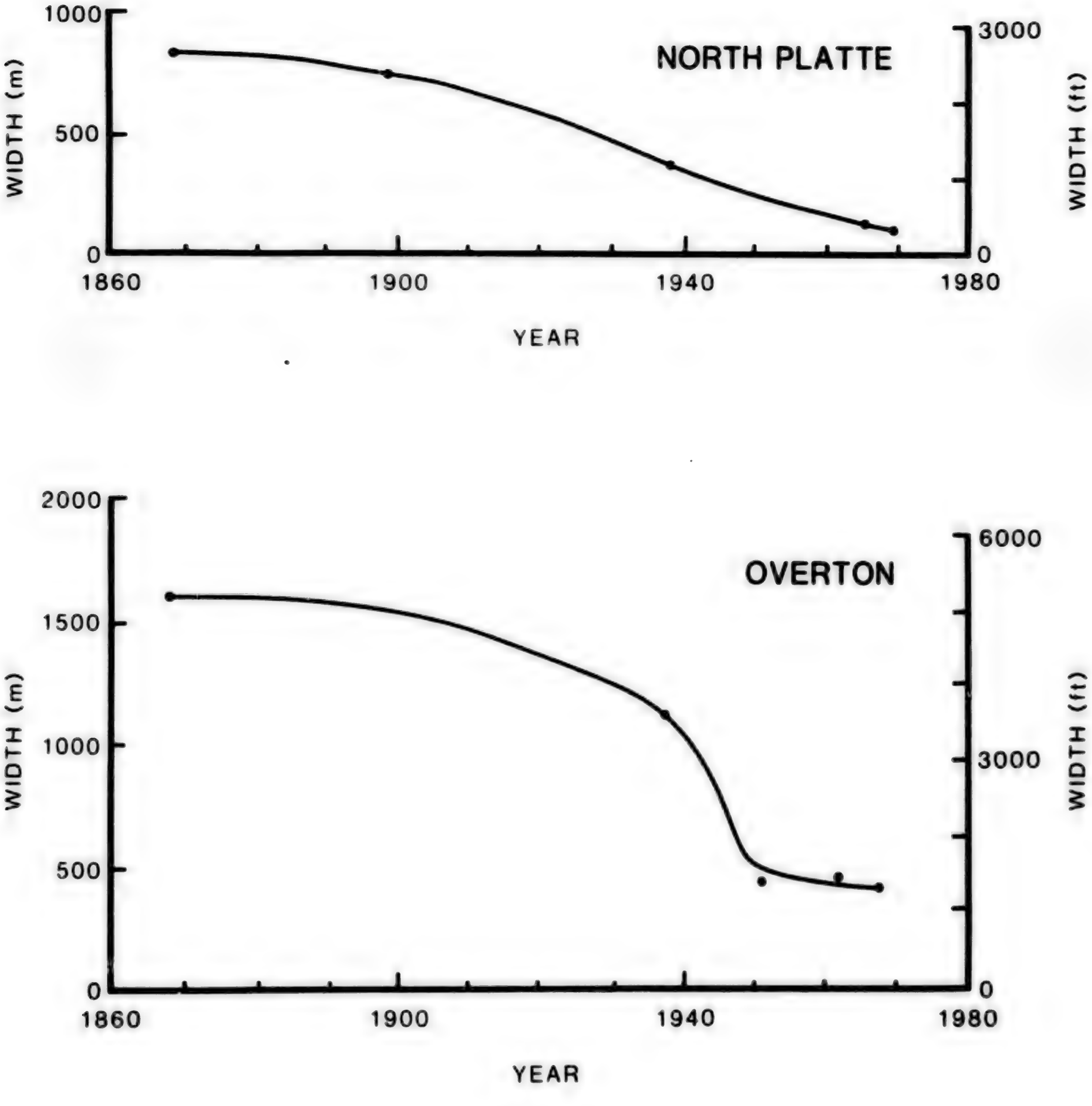


Fig. 24. Historical trends in channel widths along the North Platte and Platte Rivers at the North Platte and Overton substations (After Williams 1978).

m^3/sec) between 1910 and 1977, the general trends in hydrology were the same for the two rivers. In both instances, peak and mean annual discharge have declined substantially since 1909 (Williams 1978). Although the decline in discharge levels has been gradual since 1910, the major decline occurred after 1930. Average pre-1930 discharge levels at North Platte (86.0 m^3/sec) and Overton (107.1 m^3/sec) were nearly three times the average post-1930 discharge levels at these locations (24.6 m^3/sec, and 40.1 m^3/sec). Major increases in peak and mean annual discharge also occurred in 1971, 1973, and 1974, as a result of unusually large runoff into the North Platte and Platte Rivers from snowmelt in the Rocky Mountains (Williams 1978).

Forest Age

The age of trees and shrubs growing along the Platte and North Platte Rivers provides insight into factors contributing to the establishment of woody vegetation. The average and earliest age of cottonwood, red cedar, willow, and certain other species in riparian woodlands was determined by counting the annual growth rings on increment cores taken from trees growing along 44 transect lines sampled during a survey of the vegetation (Appendix O). Because of the high frequency of false annual rings in cottonwood and willow and the difficulties in discerning initial growth rings in all species, these age estimates are only approximate, and probably fall within 5 years of the actual dates of establishment (R. Q. Landers, pers. comm.). The development of false rings is probably minimized along the Platte, however, because the majority of trees are located on the floodplain where the water table is relatively high, and there is probably adequate soil moisture throughout the entire growing season.

The oldest trees encountered during the survey were located on uplands, old river shorelines, and raised river islands. Cottonwoods cored near Maxwell, Brady, Kearney, and Mormon Island, with establishment dates of 1900, 1894, 1881, and 1890, respectively, were the oldest trees encountered during the survey. The oldest willow and red cedar were near Overton and Kearney; both were established in 1916 (Appendix O).

Although the earliest dates of establishment provide information about the pre-1909 advancement of woody species along the Platte, the average dates of establishment are more indicative of the period when most forest development occurred. The average age of trees is shown in relation to the study sites (site 1 at Chapman to site 406 at Lake McConaughy) in Fig. 25. Trees that established along the Platte during the relatively high water discharge period before 1930 were generally found on upland sites or along the original (1890's) river shoreline. Trees growing on upland sites have been circled in Fig. 25. Exceptions to this general trend occurred at locations 229-5, 156-5, and 156-8, where diamond willow trees, established in 1926, 1925, and 1916, were growing on lowlands along the major channels. Red cedar in the understory of many of the upland sites has occurred since 1930. In one upland site (44-13) near Mormon Island, hackberry has become the predominant overstory species since 1950.

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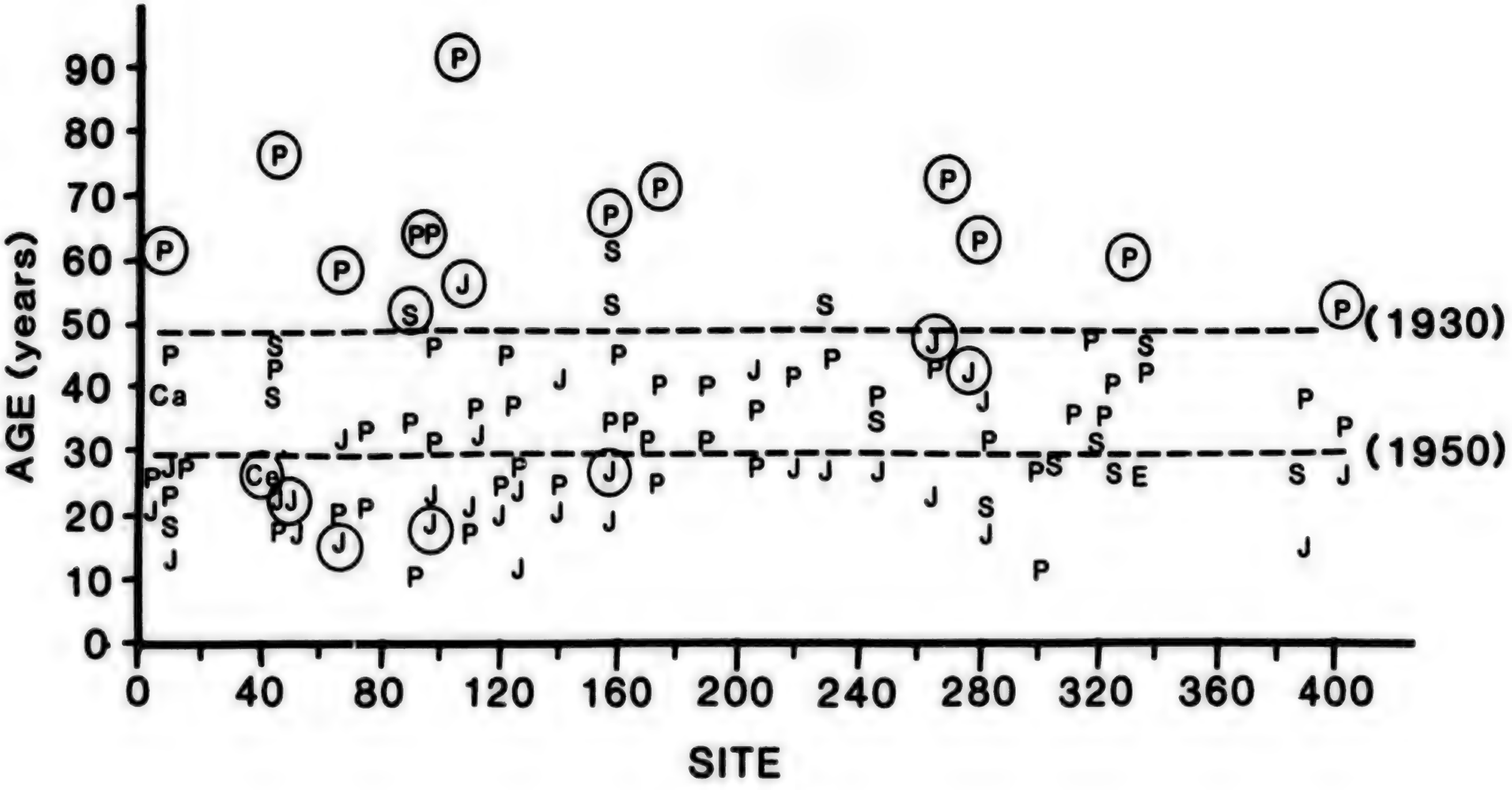

Fig. 25. Average age of cottonwood (P), red cedar (J), willow (S), catalpa (Ca), hackberry (Ce), and Russian olive (E) in relation to sample site location along the Platte River. Circled letters indicate trees growing on uplands or along the original (1890's) shoreline.

Most trees became established on the alluvial bottomlands of the North Platte and Platte River floodplains following the major decline in peak and mean annual discharge associated with the completion of Kingsley Dam and the impoundment of water to form Lake McConaughy (Fig. 24). Since 1950, establishment has been confined primarily to the understory red cedar, willow, and Russian olive in the woodlands west of Overton. Red cedar, willow, hackberry, and catalpa have developed in the understory between Overton and Chapman since 1950, but new forest establishment of cottonwood and willow has also occurred.

Cottonwood and willow were the pioneer arboreal species at all locations except at site 208-3 (Darr), and, on the average, developed 19-21 years before red cedar (Appendix O, Fig. 26). Catalpa established only 4 years after cottonwood at site 4-1, near Chapman, but because only one catalpa was cored during the study (catalpa is relatively rare along the Platte), this value may not accurately reflect the average period of establishment for this species. Estimates for establishment of Russian olive were limited to one increment core taken from a tree in a dense stand of Russian olive at site 337-3, near Hershey. Although there was widespread development of Russian olive along the North Platte, and in isolated areas along the Platte, attempts to core additional trees were not made because Russian olive has particularly tough wood and is difficult to core without damaging the increment borer. The Russian olive core was taken from a tree in what appeared to be the oldest Russian olive stand along the North Platte, and indicated that establishment occurred about 1952, approximately 15 years after cottonwood establishment. This establishment date coincides with observations made by local landowners that the majority of Russian olive establishment occurred in the late 1940's and early 1950's (Mrs. C. Summers, pers. comm. and J. Boyle, pers. comm.).

Hydrology and Radial Growth

Cottonwood was the only species for which there was a large enough sample of trees growing before 1930 that growth between the 1920-29 period when mean annual discharge was relatively high (95.6 m^3/sec on the North Platte, 112.5 m^3/sec on the Platte) could be compared to the 1930-39 period when mean annual discharge was substantially lower (43.9 m^3/sec on the North Platte, 47.2 m^3/sec on the Platte). Total incremental growth of cottonwood in the 1920-29 period averaged 53.18 mm, and declined to 46.09 mm (adjusted for senescence) during the 1930-39 period, but the difference was not statistically significant.

The effects of increased mean annual discharge on growth during 1971, 1973, and 1974 were also investigated by comparing total incremental growth of cottonwood, willow, and red cedar during 1967-70 (mean discharge 17.25 m^3/sec on the North Platte; 38.0 m^3/sec on the Platte) to total incremental growth of these species during 1971-74 (mean discharge 41.25 m^3/sec on the North Platte; 86.25 m^3/sec on the Platte). Although mean water discharge in 1972 was not particularly high, growth during this year was included with 1971, 1973, and 1974, to increase the size of the total increment, and thus reduce measurement errors. Because of the potential differences in the growth response of upland and bottomland trees to changes in hydrology, t-test comparisons were made for each species, and independently for trees on upland sites, and trees on lowland (bottomland) sites. Only total and bottomland comparisons were made for willow because only three trees of this species were cored on upland sites.

Radial growth in cottonwood declined on upland sites, increased on bottomland sites, and increased overall (total) between 1967-70 and 1971-74. None of these changes in cottonwood was large, nor was any statistically significant ($P<0.05$, Table 12). Radial growth in red cedar, however, declined significantly ($P<0.05$) on uplands, on bottomlands, and overall between 1967-70 and 1971-74. In contrast, radial growth in willow was significantly greater ($P<0.01$) during 1971-74 on both bottomlands and overall. These data indicate no significant change in the growth of cottonwood with changes in hydrology, whereas red cedar growth was inhibited and willow growth was enhanced during periods of high mean discharge.

Because willow generally establishes and develops in substantially wetter areas of the floodplain than red cedar, it is reasonable to expect that it would respond negatively to periods of low discharge, whereas red cedar would respond positively. Climatic factors such as rainfall and temperature could be partially responsible for these observed changes in radial growth. However, Johnson et al. (1976) and Everitt (1968) concluded that flood frequency and groundwater supplies, rather than climate, were the major environmental variables controlling the radial growth of floodplain trees because of nearly continuous moisture from groundwater and periodic flooding.

Vegetation-Soil Relationships

The characteristics of the soils found in 37 areas chosen as representative of the major vegetation types along the North Platte and Platte Rivers are presented in Appendix P. Grassland areas sampled along the Platte generally are characterized by well developed lowland prairie soil dominated by silty loam, and occur principally within the Leshara, Grigston, and Hobbs soil types. Except for the poorly drained sandy loam Wann soils on Mormon Island, these grasslands have moderately well-drained soils. Forest soils are usually very well drained whether they are located on uplands or on the floodplain bottomlands. Russian olive was the only woodland type found on poorly drained soils characterized by silty clay loam (Lamo) and sandy loam/clay (Las).

Russian olive establishes primarily on wet grassland sites and is usually associated with intensive grazing of wetland pastures where Lamo and Las soils dominate. In time, however, these grassland sites probably become drier because alluvial deposition and degradation of the river channel effectively elevates these sites in relation to the channel. At site 337-1 near Hershey, for example, where the oldest Russian olive stands along the Platte and North Platte were found, Russian olive is not currently establishing, and the soils are well drained and have been classified as McGrew.

Table 12. Comparison of radial growth of cottonwood, red cedar, and willow during a period of low mean discharge (1967-70) and a period of high mean discharge (1971-74). Adjusted 1971-74 radial growth (corrected for changes in radial growth with age) was used in the t-test.

Species/site	Mean radial growth 1967-70 (mm)	Mean adjusted 1971-74 radial growth (mm)	Regression equation (growth [Y] vs tree age [X])	T-values
COTTONWOOD				
Upland (33)	10.00	9.34	$Y=-0.3953X + 26.3$	-1.41
Lowland (164)	15.68	16.43		1.35
Total (197)	14.73	15.24		1.09
RED CEDAR				
Upland (28)	14.68	13.29	$Y=-0.2847X + 21.2$	-2.43 ($P<0.05$)
Lowland (38)	16.47	15.50		-1.60
Total (66)	15.71	14.56		-2.71 ($P<0.01$)
WILLOW				
Lowland (13)	13.15	17.92	$Y=-0.4052X + 30.1$	4.03 ($P<0.005$)
Total (16)	13.25	16.94		3.23 ($P<0.01$)

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Cottonwood forests were found on numerous soil types, ranging from riverwash alluvium to silty loam and clay loam. Cottonwood apparently establishes only on coarse sandy alluvium along the river channel. The subsequent soil development into a number of soil types is dependent upon the localized environmental conditions at a particular site. The appearance of most young cottonwood and willow trees on relatively undeveloped soils such as Platte and Boel and the known germination and establishment requirements of these species (Moss 1938; McLeod and McPherson 1973) support the hypothesis that these species develop only on bare alluvium. The poorly drained Lamo soils were the only soil type on which cottonwood was not abundant.

Red cedar was typically encountered on upland, well drained soils dominated by silty loam (i.e., Leshara, Grigston, Haverson) and sandy loam (i.e., Darr and Cass) soils. Red cedar was not found on the coarse-textured Platte or Boel soil types at any location except Keystone (site 404-2). At the Keystone site, however, it is suspected that red cedar originally became established on more highly developed upland soils that have subsequently been buried under layers of alluvial overwash. Nevertheless, red cedar establishes late in the vegetational sequence, generally after the development of fine textured forest soils. The upland location and the relatively dry moisture regime that characterize these sites are probably more important factors leading to red cedar establishment than the characteristics of the soils.

Vegetation Development Scheme

The following idealized vegetation development scheme was based on the classification of contemporary plant communities (Appendix M), the age structure of the forest stands, and vegetation-soil relationships. The schematic diagram in Fig. 26 illustrates the major steps in the vegetation development sequence which includes five phases. The first three phases involve sandbar and river island vegetation development and the final two stages are concerned with the vegetation dynamics in advanced stages of forest development. The vegetation sequence described in the final two stages is entirely hypothetical, because these stages in forest development have yet to be reached anywhere within the study area.

Sandbar phase (Phase I)

Exposed sandbars are rapidly colonized by annual species such as lovegrass, nutsedge, and barnyard grass during the initial phase of vegetation development. (Percentage cover values for the principal species in each habitat type are provided in Appendix N). Herbaceous perennial and biennial species such as spikerush, American bulrush, cocklebur, loosestrife, prairie cordgrass, and white sweet clover also develop at this time, but their numbers are usually small because they are not adapted for short-term, high volume seed production, and therefore they generally are not rapid colonizers. Seedlings of woody species, including cottonwood, sandbar willow, diamond willow, peach-leaf willow, American elm, and green ash, also establish during this phase of vegetation development. Hosner and Minckler (1963) and Noble (1979) observed

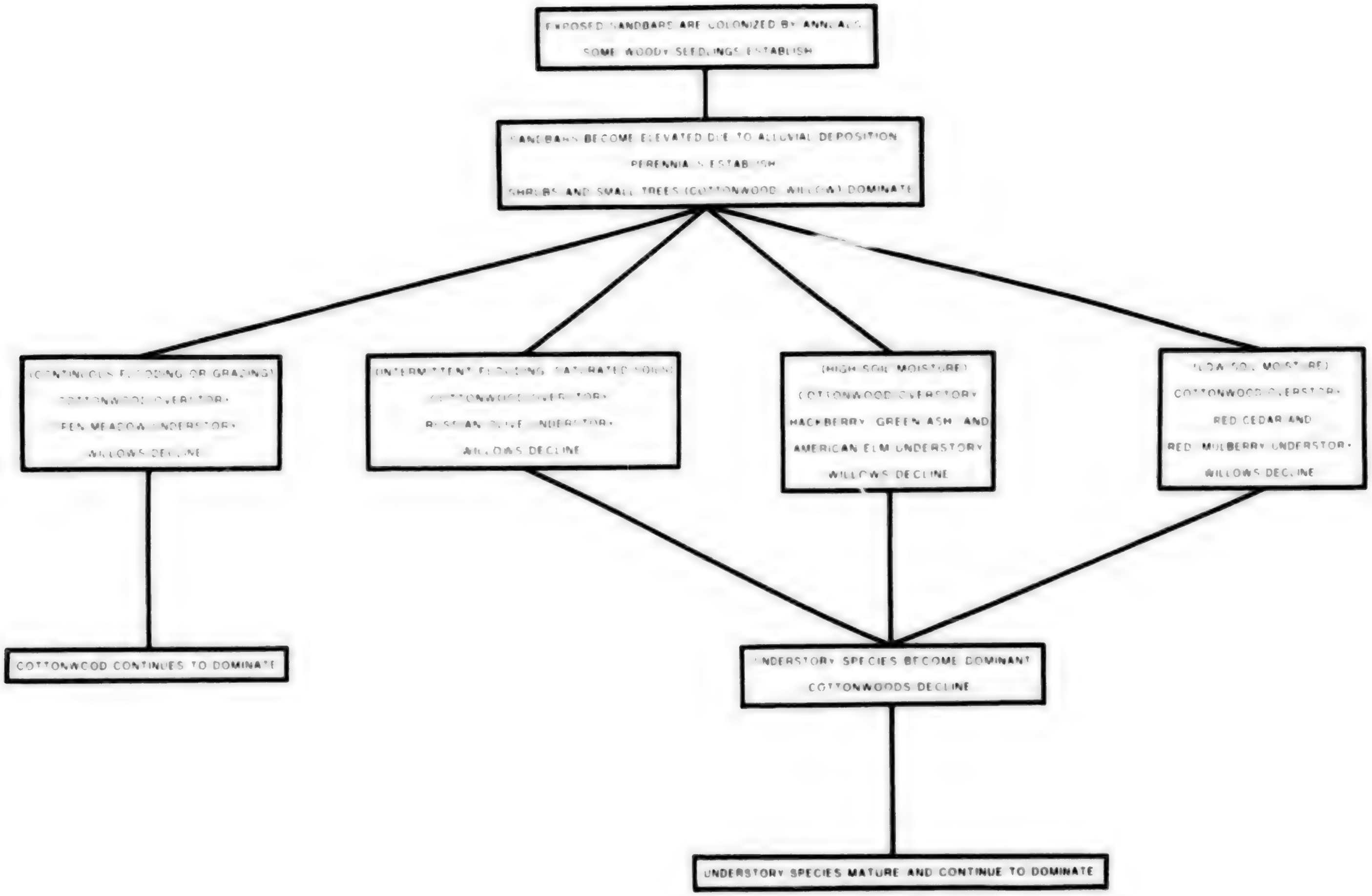
EXPOSED SANDBARS ARE COLONIZED BY ANNUALS
SOME WOODY SEEDLINGS ESTABLISH
SANDBARS BECOME ELEVATED DUE TO ALLUVIAL DEPOSITION
PERENNIALS ESTABLISH
SHRUBS AND SMALL TREES (COTTONWOOD, WILLOW) DOMINATE
(CONTINUOUS FLOODING OR GRAZING)
COTTONWOOD OVERSTORY
OPEN MEADOW UNDERSTORY
WILLOWS DECLINE
(INTERMITTENT FLOODING, SATURATED SOILS)
COTTONWOOD OVERSTORY
RUSSIAN OLIVE UNDERSTORY
WILLOWS DECLINE
(HIGH SOIL MOISTURE)
COTTONWOOD OVERSTORY
HACKBERRY, GREEN ASH, AND
AMERICAN ELM UNDERSTORY
WILLOWS DECLINE
(LOW SOIL MOISTURE)
COTTONWOOD OVERSTORY
RED CEDAR AND
RED MULBERRY UNDERSTORY
WILLOWS DECLINE
COTTONWOOD CONTINUES TO DOMINATE
UNDERSTORY SPECIES BECOME DOMINANT
COTTONWOODS DECLINE
UNDERSTORY SPECIES MATURE AND CONTINUE TO DOMINATE

Fig. 26. Idealized model of the development of woody vegetation.

American elm, green ash, box elder, and silver maple seedlings during the initial phase of vegetation development. These four woody species have airborne seeds which could easily be blown to the river floodplain, but the majority of seedlings which establish on the sandbars probably developed from seeds which have been carried in the river.

It is difficult to assess how long this phase of vegetation development persists. In many situations, flooding and scouring removes the Phase I vegetation and causes a reversion back to exposed sandbars. In other situations, the Phase I vegetation may persist for 1-5 years. During the 4-year period, annual species decline and perennials mature to a size at which major flooding and scouring is necessary to remove them.

Shrub phase (Phase II)

As the Phase I vegetation begins to stabilize the sandbars, they become elevated above the river channel from alluvial deposition on the sandbar, alluvial degradation of the river channel, or a decline in average river stage levels. Several authors (Everitt 1968; Hefley 1937; McVaugh 1957; Nickel 1978) indicate that this elevational change is primarily the result of overbank deposition. Nickel (1978) found twigs, seeds, and organic matter indicative of surface sediments, buried under several layers of alluvial sediments in soil profiles taken from Platte River islands in central Nebraska. This elevational change allows perennial species to become better established and enables them to resist removal by flooding and scouring action.

Although species composition in Phase I and II is often very similar, herbaceous species tend to dominate in Phase I, and arboreal and shrub species dominate in Phase II. The prominent Phase II shrubs include sandbar willow, indigo bush, red-osier dogwood, and rough-leaf dogwood; only sandbar willow was found in Phase I. The delayed development of indigo bush and rough-leaf dogwood is probably the result of both a limited seed source and the presence of environmental conditions that do not favor seed germination and seedling establishment of these species under Phase I.

Investigations of seedbanks from Phase I sandbars along the Platte River (Currier, unpublished data) indicated that although viable indigo bush seeds were present in the substrate, rough-leaf dogwood seeds were not. Indigo bush produces tiny indehiscent fruits which are transported via the river to sandbar sites, whereas rough-leaf dogwood seeds develop in fleshy fruits and are distributed primarily by birds. Although indigo bush seeds floating in the river should have nearly the same chance of landing on Phase I or Phase II sandbars, germination and establishment of this species generally occurs on the drier, slightly elevated Phase II sandbars. Birds carrying rough-leaf dogwood seeds, on the other hand, may preferentially land on Phase II sandbars in response to the taller, more substantial vegetation. Conditions for indigo bush and rough-leaf dogwood establishment appear to be ideal along the edges of the raised Phase II sandbars where the soil moisture is intermediate between Phase I and Phase II and large numbers of wind-rowed seeds may be deposited as river stage levels decline.

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Trees such as green ash, American elm, and hackberry may occasionally become established during this vegetation phase, but these species require a higher nutrient substrate than cottonwood and willow (Shull 1944; Rand 1973; Johnson et al. 1976) and may be confined to areas where seeds are deposited in alluvial organic material. Weaver (1960) indicates that most floodplain soils are low in nitrogen and organic matter but usually have adequate supplies of other macro-nutrients. Green ash, American elm, hackberry, and other hardwood species may require a higher nitrogen content in the soil before they can establish. Inputs of organic matter through river overwash and forest litter should increase with forest age, and thus the establishment of these species should be favored at later phases in the sequence of vegetation development.

Phase II vegetation develops during the period from 5 to 20 years after initial vegetation establishment. During this 15 year span, shrub vegetation invades, expands, matures, and then begins to decline. Sandbar willow, the pioneer shrub species along the Platte, apparently matures and degenerates after 15 to 20 years. Estimates of sandbar willow longevity range from 20 to 35 years (Wilson 1970; Noble 1979).

Young forest phase (Phase III)

Vegetation development during this phase can follow a number of patterns, depending upon local environmental conditions. Although cottonwood develops as the dominant overstory in most locations, occasionally hackberry, green ash, American elm, red cedar, or Russian olive may become the dominant arboreal species in areas where cottonwood either is not present or is relatively sparse. As a result of continued overbank deposition and degradation of the river channel, these forest sites are generally much drier than Phase I and Phase II sandbars. Sandbar willow, indigo bush, and red-osier dogwood are probably unable to reproduce under these drier conditions, and stands of these species begin to thin as individuals reach maturity and die. The present distribution of rough-leaf dogwood along the Platte, however, suggests that it is able to grow under drier conditions than indigo bush, sandbar willow, and red osier dogwood, and in many areas may replace these species.

In forests with intermittent flooding and saturated soils, Russian olive often occurs in the forest understory, whereas red cedar and red mulberry tend to dominate the understory on drier sites. These species develop late in the vegetation sequence primarily because their seeds are dispersed by birds which roost on young cottonwoods and other trees. Wind-borne seeds of hackberry, green ash, and American elm may also germinate and establish in this forest understory, these species generally occur in low-lying areas in the forest where soil moisture is relatively high and there is an accumulation of organic matter (Shull 1944; Rand 1973; Johnson et al. 1976). Robertson et al. (1978) suggest that differences in micro-relief are responsible for the distribution of arboreal species on relatively flat (i.e., less than 3 m total relief) river floodplains.

In some areas, there is no arboreal or shrub development in the forest understory. In these situations meadow vegetation develops beneath the cottonwood canopy. Such open forests may be the result of intensive grazing, poor initial establishment of shrubs, or the removal of the understory vegetation by continual deposits of alluvial overwash. Forests developing on the floodplain north of Jeffreys Island are representative of such alluvial overwash sites.

Phase III vegetation develops during the period from 20 to 50 years after initial vegetation establishment. Near the end of this phase, cottonwood and willow (primarily diamond willow) are nearing maturity, and the understory species are replacing them in dominance.

Cottonwood maturity phase (Phase IV)

The low moisture conditions in most mature floodplain forests prevents regeneration of cottonwood and willow. Therefore, when cottonwood and willow mature and die, red cedar, Russian olive, green ash, American elm, red mulberry, and other common understory species become the dominants. Only a few areas along the Platte have reached this phase of vegetation development. These areas include the red cedar/cottonwood forests near Kearney (site 106) and Maxwell (site 277), but because few of the overstory trees have actually died, the Kearney and Maxwell sites are considered to be at the initial stages of Phase IV. The length of this vegetation phase is dependent upon the longevity of cottonwood and willow trees. Cottonwood mortality has been estimated at 30 to 75 years after establishment on a number of midwestern floodplains (Shelford 1954; Read 1958; Everitt 1968). Increment tree cores from the Kearney and the Maxwell sites indicate that the oldest living cottonwood trees ranged in age from 79 to 98 years old (Appendix O). Based on these estimates of cottonwood mortality and the actual tree ages from the Platte, this phase of vegetation development has been estimated to occur at 50 to 100 years after initial vegetation development.

Maturity of understory species (Phase V)

Because there are no areas along the Platte where the forest vegetation (other than cottonwood forest) is known to be older than 100 years, vegetation development in this final phase is hypothetical. Red cedar, green ash, American elm, hackberry, red mulberry, and other species probably will dominate after cottonwood and willow have matured and died. As these species mature, they will most likely be replaced by younger individuals of the same species and therefore continue to dominate these sites. Hosner and Minckler (1963) suggested that box elder, American elm, silver maple, and green ash probably would regenerate indefinitely on floodplains along rivers in southern Illinois. Rand (1973) hypothesized a similar perpetuation of box elder, green ash, American elm, and red mulberry along the Republican River in south central Nebraska. Major shifts in the dominant species at particular sites occurs only with substantial changes in the conditions for germination and establishment of these species.

Relationship of Riverine Hydrology to Seed Viability

Cottonwood and willows are the principal as well as the pioneer woody species invading sandbars of the Platte and North Platte Rivers. Their presence on crane staging areas poses a serious threat to continued use of the River by sandhill and whooping cranes. Therefore, studies were undertaken to document the environmental conditions under which seed germination, seedling establishment, and seedling mortality occur.

Seed release

In 1979, cottonwoods released seeds from 3 June to about 26 July on riparian lands along the Platte and North Platte Rivers. The majority of the seeds, however, were released between 5 June and 20 June. Almost all of the seeds collected between 7 June and 20 June were viable. Collections after 20 June were inadequate to test viability of ripened cottonwood seeds. Previous studies indicate that cottonwood and willow release virtually all of their viable seed during May, June, and July (Ware and Penfound 1949; Kapustka 1972).

Willow seed release occurred somewhat later than among cottonwoods. The peak period of willow seed release occurred between 12 June and 20 July, but continued until 30 July. Viability of seeds rapidly decreased from 70-80% on 12 June, to 60% one week later, to 0% by 30 July. Willow seed was released for nearly 2 months, but viability of the seeds during the latter part of the seed release period undoubtedly was quite low.

Although the seed release period is relatively short, extremely large quantities of seed are produced. Kapustka (1972) estimates that a 15 cm DBH (diameter at breast height) cottonwood tree annually releases 340,000 to 650,000 seeds. Most of these seeds probably are viable but because of their short viability and seed release periods, and the limited availability of continuously moist, unvegetated substrates, few ever germinate and develop into seedlings.

Viability treatments

Seed viability curves for cottonwood and willow under experimental treatment regimes are shown in Fig. 27. The curves represent total percentage germination over a 2 week period for seeds subsampled from each treatment at intervals of 3, 7, 10, 14, 17, and 34 days. Under all treatment regimes, there was a rapid deterioration of seed viability with age. Willow seed remained viable for less than 2 weeks, whereas cottonwood seed retained its viability for nearly 3 weeks.

Although among-treatment differences in seed viability were observed, they were generally small. The largest differences were between high temperature (20-30°C) and low temperature (10-15°C) wet treatments. The high temperature wet treatments had initial (day 3) viabilities close to 100%, but because nearly all the seeds stored under this treatment had germinated by day 3, it was impossible to determine viability for longer periods of storage. Hosner (1958) observed a similar germination

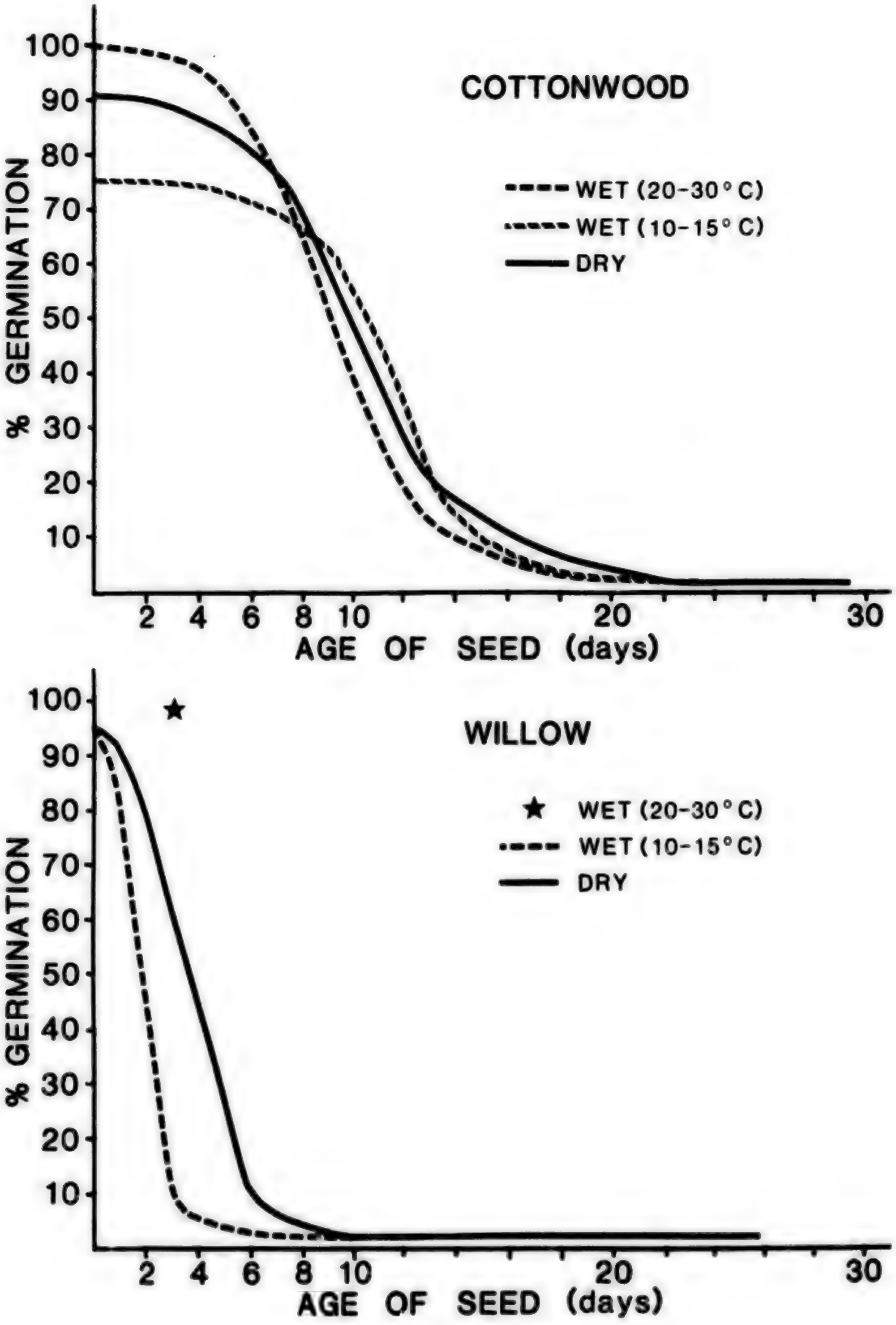

Fig. 27. Effects of riverine hydrology on seed germination rates of cottonwood and willow under various storage regimes.

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response after soaking seeds of cottonwood and willow in water for 4 days. The cottonwood treatment in which the seeds were stored with their pappus hairs was the only high temperature wet treatment in which the seeds did not all germinate within 3 days. Seed viability under this latter treatment, however, declined more rapidly than for all other cottonwood treatments (i.e., from 100% at day 3, to 80% at day 7, less than 10% at day 14, and 0% by day 17).

Wet treatments at the lower temperature regime (10-15°C) had much lower initial (day 3) viabilities for cottonwood (75%) and willow (30%) than under the higher temperature regime. Because seeds stored under wet conditions at 10-15°C did not all germinate within 3 days, viability determinations could be conducted for a longer period of time than under the higher temperature regime. Viability data generally indicate that the lower temperature regime slowed both the initial germination response and the decline in viability over time.

The seed viability curves for the dry treatments in both cottonwood and willow are intermediate between those for the high and low temperature wet treatments. Although initial (day 3) viability for willow under the dry treatment was nearly 95%, it dropped to less than 10% by day 7, and was 0% by day 14. Cottonwood viability declined less rapidly under the dry treatment regime, from an initial (day 3) 90-95%, to 80-90% at day 7, 17% at day 14, 3% at day 17, and 0% by day 34.

These findings are in agreement with the results of previous studies. Although cottonwood has been estimated to remain viable for up to 7 weeks (Horton et al. 1960), most studies place its viability at 2 to 4 weeks (Moss 1938; Ware and Penfound 1949; Kapustka 1972). Willow has been shown to have a shorter period of seed viability of only 1 to 3 weeks (Moss 1938; Ware and Penfound 1949; McLeod and McPherson 1973). By storing seeds at 10% relative humidity, Moss (1938) was able to extend the limited viability periods of cottonwood and willow to 8-10 weeks.

Relationship of Riverine Hydrology to Seedling Establishment and Survival

Although 71 permanent 1x1 m quadrats on the floodplain were monitored for seedling establishment and mortality, seedlings were encountered in only 17 (Table 13). A total of 307 mature seedlings (i.e., present at the initiation of the study) were recorded, but only 26 new seedlings were established in these 17 quadrats during the study. The mature seedlings were found on sandbars, in upland shrubland, and in upland woodlands, whereas new seedlings became established exclusively on sandbars (Fig. 28). Two-thirds of all the mature and new seedlings were found in quadrats adjacent to a narrow river channel at the Mormon Island site. Most of the new seedling establishment occurred in quadrats where mature seedlings were already present.

Seedling mortality was almost exclusively confined to sandbar sites, where the majority of seedlings were located. Most seedling mortality occurred between 17 June and 16 July when river stage levels were high. All new seedlings became established after stage levels declined in mid-July, and most survived until the study was terminated on 30 September.

Table 13. Occurrence, establishment, and mortality of seedlings in 17 permanent 1-m^2 quadrats. Mature seedlings refers to those present before the study.

Location	Mature seedlings	New seedlings	Total seedlings	Mortality	Survival
Jeffreys Island	0	1	1	0	1
Jeffreys Island	7	2	9	2	7
Jeffreys Island	18	1	19	4	15
Mormon Island	13	1	14	13	1
Mormon Island	3	0	3	0	3
Mormon Island	14	9	23	12	11
Mormon Island	209	8	217	93	124
Mormon Island	2	0	2	0	2
Mormon Island	6	0	6	3	3
Audubon Bird Sanctuary	0	1	1	0	1
Audubon Bird Sanctuary	12	0	12	4	8
Audubon Bird Sanctuary	1	2	3	1	2
Audubon Bird Sanctuary	1	1	2	0	2
Audubon Bird Sanctuary	10	0	10	10	0
Audubon Bird Sanctuary	4	0	4	0	4
Audubon Bird Sanctuary	6	0	6	1	5
Audubon Bird Sanctuary	1	0	1	0	1

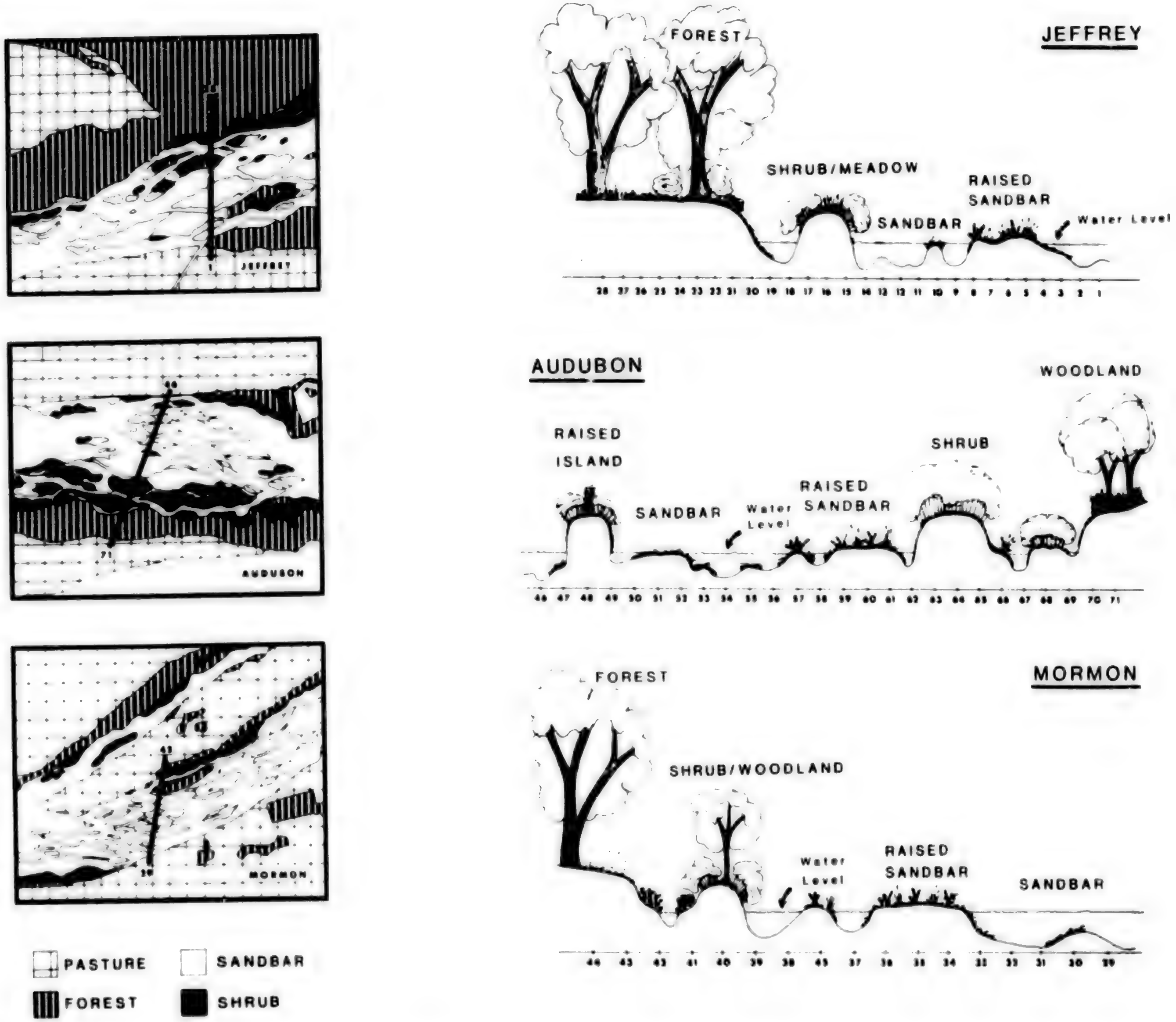

Fig. 28. Habitat conditions at 3 vegetation study sites. Vegetative cover and location of transect lines (left) and profiles indicating relative elevation of the 71 permanent quadrats (right).

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Seedling establishment is seldom, if ever, limited by seed availability because a large volume of viable cottonwood and willow seed is transported via the river. Sandbar availability, however, undoubtedly is very crucial to cottonwood and willow seedling establishment. For example, although the Jeffrey Island site was located closest to a cottonwood forest (Fig. 28), and thus within close proximity to a potentially large seed source, sandbars were limited, and seedling establishment was the lowest of three study locations (Table 13). At the Audubon and Mormon Island sites, forests were less abundant, but sandbars were more extensive and substantially greater seedling establishment occurred (Fig. 28, Table 13).

Seedling relationships to environmental parameters

New seedling establishment was the only dependent variable for which statistically significant ($P<0.05$) relationships could be shown with the environmental parameters based on multiple regression analyses. The best model is

$$\hat{Y} = -0.29793 + 0.01958X_1 - 0.01128X_2 + 0.03825X_3$$

where $\hat{Y}$ is the number of new seedlings, X_1 is percentage fine sand, X_2 is percentage silt, and X_3 is critical percentage soil moisture (Appendix Q). Positive relationships exist between seedling establishment and percentage fine sand and percentage soil moisture during the critical establishment period, and a negative relationship between percentage silt and seedling establishment. Critical moisture is the most highly significant ($F = 4.79$, $P = 0.0322$) variable in the model.

Whereas the regression analysis was used to model the environmental conditions under which seedling establishment took place, a reciprocal averaging technique was designed to identify groups of quadrats with similar environmental characteristics, and then to investigate the relationships between seedling and environmental variables in each group. The reciprocal averaging ordination of the 71 permanent quadrats monitored during the study is based on 12 environmental parameters (Appendix Q). The quadrats were divided into three broad habitat types based on their positions in the ordination: upland, raised sandbar, and sandbar.

The distribution of seedlings along the moisture gradient confirms previous observations (Table 13) that mature seedlings were found on both upland and sandbar sites, but new seedlings became established only on sandbars. Among the sandbar sites, however, the raised sandbar supported the greatest number of new seedlings.

The 71 permanent quadrats were grouped into 5 types of sites, based on the 3 broad habitat types (i.e., upland, raised sandbar, sandbar) and the presence of new seedlings. These five groups are upland (U), raised sandbar (R), raised sandbar with new seedling establishment (RS), sandbar (S), and sandbar with new seedling establishment (SS).

Means for all the seedling and environmental parameters in each of the five types of sites are presented in Table 14 and definitions of the

Table 14. Means of the environmental and seedling parameters for quadrats included in the upland, raised sandbar, raised sandbar with new seedlings, sandbar, and sandbar with new seedlings sites. Within each parameter, means with the same letter are not significantly different ($P<0.05$, Duncan's Multiple Range Test).

Parameters	Sites				
	Upland	Raised sandbar	Raised sandbar with new seedlings	Sandbar	Sandbar with new seedlings
SOIL MOISTURE (%)					
Average	21.8 a	22.9 a	28.4 a	12.3 b	10.0 b
Critical	19.8 a	20.3 a	28.0 a	11.8 b	9.1 b
Minimum	10.2 b	10.2 b	17.5 a	7.8 b	6.3 b
SOIL TEXTURE (%)					
Coarse gravel	1.1 c	2.0 c	0.7 c	10.6 b	25.0 a
Gravel	1.2 c	6.5 b	2.9 bc	15.3 a	16.5 a
Sand	53.5 b	61.8 ab	62.6 ab	65.2 a	51.5 b
Fine sand	15.2 a	11.1 ab	14.6 a	4.4 b	5.9 ab
Silt	29.0 a	18.7 b	19.1 b	4.5 c	1.0 c
WATER REGIME					
Exposures (days)	77.0 b	75.5 b	74.2 b	33.6 a	49.7 ab
Average depth (cm)	0.0 c	2.4 c	3.6 bc	15.6 a	9.5 ab
Total maximum (cm)	0.0 c	30.7 b	26.1 b	73.5 a	86.0 a
Critical maximum (cm)	0.0 b	3.2 b	5.3 b	36.5 a	39.0 a
SEEDLINGS					
Mature (initial)	0.7 b	0.7 b	37.6 a	0.7 b	0.0 b
New establishment	0.0 b	0.0 b	3.4 a	0.0 b	1.0 b
Total (mature + new)	0.7 b	0.7 b	41.0 a	0.7 b	1.0 b
Mortality	0.1 b	0.3 b	17.9 a	0.5 b	0.0 b

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environmental parameters are presented in Appendix Q. Analysis of variance indicated that, except for percentage sand, there were significant differences ($P<0.05$) in the means for all parameters among the five types of sites.

Because the majority of seedling establishment and seedling mortality occurred at RS sites, comparisons were made between the environmental conditions at these sites and those at all other sites. In many instances, the environmental conditions at the RS sites did not differ significantly ($P<0.05$) from those which characterized the U and R sites. For example, average percentage soil moisture, critical percentage soil moisture, percentage coarse gravel, percentage sand, percentage fine sand, days of substrate exposure, average water depth during flooding, and critical maximum water depth did not differ significantly among the RS, R, and U sites. Although exposure, average water depth, and critical maximum water depth at the RS sites did not differ significantly from the values for these parameters at the U sites, the sites differed fundamentally because the U sites were never flooded. The values for total maximum water depth in the RS and R sites were substantially greater than in the U sites and thus these differences between the U and the R and RS sites were statistically significant. The similarity of the water regime parameters for the R and RS sites was not unexpected because these sites are located at approximately the same elevation on the floodplain (raised sandbars) and were separated only on the basis of the presence of new seedlings.

Soil texture in the RS sites did not differ from that in the R sites. The U sites, however, had a significantly greater percentage of silt than either the R or RS sites. The percentage gravel in the R sites also was significantly greater than that in the U sites, but there was no significant difference between the percentage gravel in the RS sites and that in either the R or the U sites.

All three soil moisture parameters were highest in the RS sites, intermediate in the R sites, and lowest in the U sites. Minimum percentage soil moisture, however, was the only soil moisture parameter which was significantly greater in the RS than in the R or U sites. Soil moisture is critical for the survival of embryonic cottonwood and willow seedlings (Moss 1938), consequently this difference in minimum percentage soil moisture probably is responsible for the significantly greater seedling establishment and numbers of mature seedlings found in the RS sites.

Although there were many similarities in the environmental characteristics of the RS, R, and U sites, there were major differences in the environmental characteristics of the RS and the S and SS sites. In general, the S and SS sites are characterized by shorter periods of substrate exposure, greater water depths, a greater percentage of coarse sediments, and lower percentage soil moisture than in the RS sites.

Comparisons between the RS and the U, R, S, and SS sites indicate that the relatively high percentage soil moisture, fine textured soils, long period of substrate exposure, and moderate water depth during flooding make the RS sites particularly favorable for seed germination and seedling establishment. The number of mature seedlings in the RS sites was also significantly greater than in all other types of sites, suggesting that the RS sites have served as successful habitats for seed germination and establishment in the past. Although mature seedling mortality was significantly greater in the RS sites than elsewhere, this is most likely the result of larger seedling numbers in the RS sites rather than actual differences in mortality rates.

The establishment of seedlings in SS sites on two separate quadrats is more difficult to explain than seedling establishment at the RS sites. The low percentage soil moisture, the coarse, porous sediments, and the relatively short exposure period at the SS sites are not particularly favorable conditions for seedling establishment. However, the greater water depth and more frequent flooding at these sites may compensate for the poor moisture-retaining capacity of the soils and provide an adequate moisture regime for seed germination and seedling establishment. The lack of mature seedlings and the relatively deep water regime at the SS sites suggest that, although seedling establishment can occur, the probability of seedling survival is quite low.

MAINTENANCE OF CRANE HABITAT

Potential Effects of Habitat Degradation

Research findings summarized in this Report underscore the need to prevent further deterioration of crane habitat and thereby reduce the pressures that have already caused the abandonment by sandhill cranes of about two-thirds of the original channel habitat available in the Platte and North Platte River Valleys. With about 80% of the continental population of sandhill cranes staging along approximately 70 miles of the Platte and North Platte Rivers each spring, the crane population already is confined to a relatively small area.

Crowding of the crane population into a smaller land and water base poses several potential hazards. First, as the habitat base continues to shrink, the probability of catastrophic losses to natural forces such as ice storms, hail storms, or tornadoes increases. Such phenomena are often not very widespread, but can have a devastating impact on wildlife populations. Cranes are known to be vulnerable to severe hailstorms (Merrill 1961; Higgins and Johnson 1978; Heflebower and Klett 1980). The occurrence of hailstorms in Nebraska during March and April of the past 25 years (U.S. Environmental Data Service 1959-80) indicates the potential for heavy losses in view of the high concentrations of birds present in the Platte Valley.

Crowding also increases the likelihood of food shortages if present land use practices change and access to corn diminishes substantially. The present supply of waste corn on the study area during the spring staging period is more than adequate to meet maintenance requirements and to build fat reserves for migration and reproduction. The crane population could have difficulty meeting its caloric requirements if corn availability declines due to increased fall tillage, conversion of cropland from corn to a less energy-rich and digestible crop, or for some other reason. The continuing loss of native grasslands poses the threat of shortage of the invertebrate foods that provide much of the protein and calcium in the diet. Habitat deterioration in the river channel and the resultant crowding is leading to intensive use of the grassland tracts that remain accessible to the crane population.

Lessening vulnerability to disease represents the third reason for maintaining a dispersed population of cranes. If conditions along the Platte continue to deteriorate, cranes will shift into areas of the River still containing suitable habitat, thus increasing the density of cranes on these sites. Beyond some threshold level of habitat deterioration cranes will seek roosting sites elsewhere; the Rainwater Basin Area to the south of staging areas 1 and 2 is a probable alternative site. Sandhill cranes already occasionally gather there during the spring staging period but in relatively small numbers (Appendix K). Whooping cranes, which may be more sensitive than sandhill cranes to habitat deterioration, have been sighted in this area regularly in recent years. Greater use of the Rainwater Basin Area by cranes would increase the probability of mortality due to avian cholera and other diseases. Because less than a hundred whooping cranes exist in the population, loss of a few individuals would have a major impact.

Native Grassland

The native grasslands of the Platte and North Platte River Valleys function as a primary source of protein and calcium for sandhill cranes during the spring staging period. Although corn is the principal energy source, it contains inadequate levels of calcium and certain amino acids. Native grasslands probably serve a similar function in supplying protein and minerals for whooping cranes (Appendix R). Therefore, preservation of native grassland tracts at strategic locations should be an integral part of the overall habitat management plan for meeting the needs of the crane populations.

Native grassland habitat should be preserved in a distribution that will ensure access by all segments of the staging crane population in order to meet nutritional requirements and maintain the current dispersal pattern. The first priority in preservation of grassland habitat should be to protect those remaining large grassland tracts which lie adjacent to the river channel in areas where major roosts are located.

It is preferable to maintain the grassland tracts in close proximity to roosting habitat. Close proximity of grassland tracts to the channel reduces daily crane movements and the energy cost associated with acquiring adequate protein and calcium. Prolonged flights to obtain these nutrients would require a substantial energy expenditure. This strategy will help to lessen the impact of any future alterations of the present corn-livestock economy that would reduce crane access to high energy foods. Second, cranes using grassland tracts adjacent to the channel are less subject to various types of human disturbance. Disturbance is less of a problem near the river channel in most areas because major highways do not intersect flight lanes and land ownership patterns and agricultural practices discourage travel there. Loss of key tracts of grassland habitat near the River would likely result in movement to areas less protected from disturbance.

Based on the present distribution of sandhill cranes and habitat requirements of the population, the most appropriate habitat maintenance plan would be to protect, through purchase in fee title, a series of tracts near the River ranging in size from a few hundred to several thousand acres. These reserves, which would be managed specifically to satisfy crane requirements, would consist principally of grassland and channel habitat but would also contain limited cropland. In some areas, it may be necessary to restore grassland habitat to increase crane access to invertebrate foods. Each unit would be centered on a major roosting area and should preferably include several km of river channel both upstream and downstream to allow intensive management of roosting habitat. Some areas should include a 200+ m wide channel to accommodate whooping cranes. Between the principal management units, grassland tracts existing on the staging areas and within 3.2 km (2 miles) of the channel should also receive protection, possibly through easements.

The Lillian Annette Rowe Sanctuary of the National Audubon Society and the Terry tract on Mormon Island acquired by the Whooping Crane Critical Habitat Maintenance Trust Fund in 1980 and managed by the

Nature Conservancy are indicative of the type of reserves needed at several strategic sites. Both are principally native grassland and channel habitat situated in areas supporting high numbers of cranes. These reserves, if expanded, would sustain major segments of the staging crane population during spring in the Platte Valley.

Grasslands will require certain management practices to ensure continued high use by cranes. Cranes prefer grassland with relatively short vegetation and largely avoid tracts of tall rank cover. Most crane use in the Valley occurs on native grasslands receiving moderate grazing pressure by livestock. Burning provides an alternative management technique to grazing that is acceptable to cranes. In situations where rank stands were burned during the staging period, cranes occupied the sites almost immediately after burning. Sandhill cranes sampled while foraging at these sites were feeding principally on earthworms. In 1980, two whooping cranes were attracted to a recent burn on the Lillian Annette Rowe Sanctuary, suggesting that burning may be useful in attracting whooping cranes to managed units along the River. Data obtained in this study suggest that both grazing and burning or a combination of both practices maintain habitat in a condition suitable for cranes during the spring-staging period. However, additional research is needed to determine grassland management practices most conducive to optimizing production of the invertebrate foods sought by cranes.

Although the high water table on lands adjacent to the river channel and associated water-logged soils have discouraged tillage in the past, there has been a gradual lowering of the water table and a concurrent encroachment by agriculture upon the remaining grasslands in recent years. Because this trend will probably continue, it is important that acceptable methods be found to protect strategic areas along the river in the near future.

Channel Habitat

This study established the importance of wide, shallow, unobstructed river channels for roosting sandhill cranes. River segments with open water at least 150 m wide supported nearly 70% of all roosting cranes in 1979, although only 25% of the segments sampled had channels of this width. Over 18% of the river segments have a maximum unobstructed channel less than or equal to 50 m wide, but less than 1% of the cranes roosted on them. Crane use of river segments in which the maximum channel width was between 51 and 150 m was less than expected based on its availability, except where average bank vegetation was less than 0.5 m high.

Before extensive upstream diversion of the North Platte and South Platte Rivers, flows were adequate to maintain a wide channel and suitable roosting conditions throughout the reach under study. River stage levels during the early and mid-summer months kept sandbars and mudflats submerged, thereby preventing the establishment of woody vegetation. Vegetation that became established later in summer probably was cleared from the channel both by the scouring action of ice and by high flows during the following spring and the concomitant shifting of alluvial sediments. Peak flows in spring are now largely retained upstream in reservoirs. Increased consumptive use of the Platte's waters has reduced average annual flows in some areas to less than 20% of levels present 100 years ago. As a result of flow reduction, permanent islands supporting woody vegetation are now a common feature of the River, channel width has been drastically reduced in many areas, and extensive woodlands are now rooted in sediments which were formerly parts of the channel. Cranes are extremely wary birds and tend to avoid roosting in areas where vegetation is tall and channel width is narrow.

The natural establishment of woody vegeation must be controlled to maintain roosting habitat for sandhill and whooping cranes. This study has quantitatively documented that seedling establishment of cottonwoods and willows, the predominant trees to invade sandbars and former channel lands of the Platte Valley, occurs primarily on sites with a high percentage soil moisture, fine textured soils (i.e., sand and fine sand), and an extensive substrate exposure period during the time when viable seed is available. Viable seeds are released from mid-May to mid-July, but individual cottonwood seeds remain viable for only 3 weeks, and willow seeds remain viable for less than 2 weeks. Under these circumstances, viable seed is available during the seed release period (mid-May to mid-July), and for approximately 1 month after seed dispersal (i.e., until the end of August). Sandbars with high soil moisture levels must be exposed for at least 1-2 weeks during this mid-May to August viability period if seeds are to germinate and seedlings become established.

Water manipulation is probably the most effective means of controlling encroachment by woody vegetation. When seedlings become established, major floods and scouring are necessary to remove them. Field observations by Shull (1944) and Dietz (1952) have shown that cottonwood and willow seedlings and saplings are quite resistant to the effects of flooding. Hosner (1958) experimentally demonstrated that 7.6 cm (3 inch) cottonwood seedlings could survive 16 days of inundation but that recovery was very slow. Willow seedlings were able to survive the same treatment for 32 days and recovered very rapidly. Experiments conducted with Platte River seedlings 15 cm tall indicated that cottonwood was able to survive 30 days of inundation, and recovered completely after the flooding. The 15-cm seedlings were chosen for the latter study because they were representative of seedlings that established on Platte River sandbars in July and August of 1978, when the substrate was exposed for 4-5 weeks. A similar but later exposure of the substrate occurred in August and September of 1979. If this water regime is typical of most years along the Platte, seedlings that become established in mid-summer would probably have ample opportunity to develop to a height of 15 cm or greater. Manipulation of river stage levels during the fall, winter, or spring, when demands on river water for irrigation are minimal, would undoubtedly remove some of the seedlings that became established during the previous summer, but this technique would probably not be very effective in removing seedlings 15 cm or taller.

Seed germination and seedling establishment can be most effectively controlled by raising river stage levels during the seed viability period (mid-May to August), inundating sandbars either throughout the period of seed germination or for sufficient time to prevent seed germination and seedling establishment. During the present study, seedling establishment occurred primarily on raised sandbars which, on the average, were exposed at stage levels (relative to the Overton gaging station) less than 0.70 meters (2.3 feet). Stage levels averaged 0.82 meters (2.7 feet) during the early portion of the summer (10 June to 16 July) and thus were adequate to prevent seedling establishment. From 16 July to 30 September, however, stage levels averaged only 0.47 meters (1.5 feet) and numerous sandbars were exposed and seedlings became established. Mean stage levels would have to be kept above 0.79 meters (2.6 feet) for all or part of May, June, July, and August, when viable seeds are present along the Platte to successfully prevent seedling establishment.

Alternative methods will be needed to control existing stands of woody vegetation, particularly on islands within the channel because water is only partially effective in removing seedlings after establishment. Chemical and mechanical techniques probably are the most effective tools, but are both costly and labor intensive, and require repeated use in order to ensure successful control of woody vegetation. A thorough evaluation of the effectiveness of specific chemical and mechanical techniques for control of woody vegetation is needed before guidelines for their use can be formulated.

In view of the effect of channel width and vegetation height on crane use of the river, management techniques will be needed to prevent further channel shrinkage and woody vegetation encroachment on islands. The findings of the study suggest that a long-term management goal should be to maintain unobstructed river channel width at a minimum of 150 m throughout the staging areas. Reaches of river channel within management units that are either in public ownership or otherwise managed specifically for cranes should be maintained with channels at least 200 m wide to accommodate the needs of whooping cranes, which appear less tolerant of woody vegetation.

Among the 91 0.8 km (0.5 mile) segments within staging area 1, 65 contain unobstructed channels over 150 m wide and 28 of these have channels over 200 m in width (Appendix I). Only five of the segments with wider channels were not utilized for roosting by cranes and each of these had either a bridge crossing the river or a road immediately adjacent to it. Although the quality of roosting habitat in staging area 1 has been deteriorating, most of it is still acceptable to cranes and, therefore, receives heavy use. Management of river flows to maintain unobstructed channel width at a minimum of 150 m throughout staging area 1, and at a width of 200 m in certain restricted sections, should be adequate to satisfy the habitat requirements of roosting cranes. Control of woody vegetation on some river channel islands will be necessary to prevent the vegetation from reaching a height that will inhibit roosting.

Within staging area 2 only 20 of the 50 0.8 km (0.5 mile) segments have channels over 150 m wide, and much of the western half of this staging area (segments 148-171, Appendix I) has been abandoned by cranes during recent years. Although birds continue to use this staging area, many cranes probably have recently shifted to staging area 1. Further deterioration will very likely lead to additional shifts. Channel habitat in the Overton area, a key staging site in historic times and an area formerly used by whooping cranes, is threatened and some reaches are gradually being abandoned. Habitat conditions on much of the eastern half of staging area 2, which still supports large numbers of roosting cranes, are approaching a critical condition. In contrast to staging area 1, most island vegetation in staging area 2 exceeds 8 m in height. Much of staging area 2, particularly the western half, will probably require extensive rehabilitation of channel habitat to restore suitable roosting conditions. Initial management should concentrate on maintaining open channels over 150 m wide in the eastern half of the staging area and on clearing island vegetation, particularly at western sites where abandonment by cranes appears imminent.

Staging area 3 is quite unlike staging areas 1 and 2. Less than 10% of the 0.8 km (0.5 mile) segments contain channels over 150 m wide, and in fact, 75% of them are less than 100 m in width. Low vegetation on islands and banks (<8 m) may account for continued crane use despite the relatively narrow width of the channel. However, substantial island vegetation is in the 4 to 8 m height class, indicating that the trees are well established and will probably grow to a sufficient height to adversely affect roosting, particularly when one considers the narrow width of the river channel. The most appropriate management in staging area 3 seems to be application of procedures to prevent further establishment of woody vegetation and to remove existing woody vegetation on those river islands where the combination of channel width and vegetation height is most likely to inhibit crane use.

Public Facilities

Along with habitat preservation, adequate facilities are needed at certain of the reserves to allow the many visitors that travel to the Platte Valley to view cranes in natural settings without having their presence disrupt the crane population. Development of areas managed specifically for the cranes and other migratory birds, and with adequate facilities to accommodate visitors, would largely eliminate the disruption to both landowners and cranes which has accompanied the influx of crane watchers in recent times.

In the absence of facilities and public lands, visitors now gather along public roads often creating traffic congestion and related problems. Opportunities also exist to attract large numbers of travelers throughout the year because of the close proximity of I-80 to the river channel and, with the aid of a well-designed visitor center, to educate the public to the unique features of the Platte River Valley and its significance in meeting the needs of midcontinent migratory bird populations. The fascinating history of the Platte River Valley and the importance of wildlife populations in the settlement period adds to the potential scope of the exhibit.

REFERENCES

Albertson, F. W., and J. E. Weaver. 1945. Injury and death or recovery of trees in prairie climate. Ecol. Monogr. 15:393-433.

Allen, R. P. 1952. The whooping crane. Natl. Audubon Soc. Res. Rep. 3. 246 pp.

American Fisheries Society. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd edition. Spec. Publ. 6. Am. Fish. Soc., Bethesda, Maryland. 149 pp.

American Ornithologists' Union. 1957. Check-list of North American birds, 5th ed. Am. Ornithol. Union, Baltimore, Maryland. 691 pp.

American Ornithologists' Union. 1976. Thirty-third supplement to the American Ornithologists' Union check-list of North American birds. Auk 93:875-879.

Ankney, C. D., and C. D. MacInnes. 1978. Nutrient reserves and reproductive performance of female lesser snow geese. Auk 95:459-471.

Arbib, R. 1978. The blue list for 1979. Am. Birds 32:1106-1113.

Baker, R. R. 1978. The evolutionary ecology of animal migration. Holmes & Meier Publ., New York. 1012 pp.

Bell, J. F., G. W. Sciple, and A. A. Hubert. 1955. A microenvironment concept of the epizoology of avian botulism. J. Wildl. Manage. 19:352-357.

Bellrose, F. C. 1972. Mallard migration corridors as revealed by population distribution, banding and radar. Pages 3-26 *in* Population ecology of migratory birds. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 2.

Bennett, J. W., and E. G. Bolen. 1978. Stress response in wintering green-winged teal. J. Wildl. Manage. 42:81-86.

Bentall, R. 1975. Hydrology, Nebraska mid-state division and associated areas. Univ. of Nebraska, Institute of Agriculture and Natural Resources, Lincoln. 256 pp.

Bessey, C. E. 1899. Are the trees advancing or retreating upon the Nebraska plains? Science 10:768-770.

Borchert, J. R. 1950. The climate of the central North American grassland. Ann. Assoc. Am. Geogr. 40:1-39.

Bose, D. R. 1977. Rangeland resources of Nebraska. U.S. Soil Conserv. Serv., Lincoln, Nebraska. 121 pp.

Brooking, A. M. 1934. The whooping crane in the spring of 1934. Nebr. Bird Rev. 2:117-118.

Brooking, A. M. 1943a. The present status of the whooping crane. Nebr. Bird Rev. 11:5-8.

Brooking, A. M. 1943b. Additional records of the whooping crane. Nebr. Bird Rev. 11:47.

Brooking, A. M. 1944. Additional records of the whooping crane. Nebr. Bird Rev. 12:7.

Bryson, R. A. 1966. Air masses, streamlines and the boreal forest. Geogr. Bull. 8:228-269.

Buller, R. J. 1975. Redistribution of waterfowl: influence of water, protection, and feed. Int. Waterfowl Symp. 1:143-154.

Buller, R. J. 1979. Lesser and Canadian sandhill crane populations, age structure, and harvest. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. 221. 10 pp.

Burgess, E. C., J. Ossa, and T. M. Yuill. 1978. Duck plague: a carrier state in waterfowl. Univ. of Wisconsin, Dep. Vet. Sci. 13 pp. Unpubl. rep.

Craighead, J. J., and F. C. Craighead. 1969. Hawks, owls, and wildlife. Dover Publications, New York. 443 pp.

Donahue, J. M., and L. D. Olson. 1969. Survey of wild ducks and geese for *Pasteurella* spp. Bull. Wildl. Dis. Assoc. 5:201-205.

Drobney, R. D. 1980. Reproductive bioenergetics of wood ducks. Auk 97:480-490.

Edwards, C. C. 1969. Winter behavior and population dynamics of American eagles in western Utah. Ph.D. Thesis, Brigham Young Univ., Provo. 142 pp.

Enright, C. A. 1971. A review of research on type C botulism among waterbirds. Coop. Wildl. Res. Unit Colorado State Univ., Fort Collins. 22 pp.

Everitt, B. L. 1968. Use of cottonwood in an investigation of the recent history of a floodplain. Am. J. Sci. 266:417-439.

Frederick, R. B. 1979. Resource utilization and behavior of migrating snow geese at DeSoto National Wildlife Refuge. M.S. Thesis, Iowa State Univ., Ames. 68 pp.

Frith, C. R. 1974. The ecology of the Platte River as related to sandhill cranes and other waterfowl in south central Nebraska. M.S. Thesis, Kearney State College, Kearney, Nebraska. 115 pp.

Geis, A. D. 1971. Breeding and wintering areas of mallards harvested in various states and provinces. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. 144. 59 pp.

Gleason, H. A. 1922. The vegetational history of the Middle West. Ann. Assoc. Am. Geogr. 12:39-85.

Great Plains Flora Association. 1977. Atlas of the Flora of the Great Plains. Iowa State Univ. Press, Ames. 600 pp.

Grieb, J. R., and E. L. Boeker. 1954. Waterfowl migration studies and their application to management in Colorado. Trans. N. Am. Wildl. Conf. 19:195-210.

Griffin, C. R. 1978. The ecology of bald eagles wintering at Swan Lake National Wildlife Refuge, with emphasis on eagle-waterfowl relationships. M.S. Thesis, Univ. Missouri, Columbia. 185 pp.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. Ronald Press, New York. 1083 pp.

Hansen, A. J. 1977. Population dynamics and night roost requirements of bald eagles wintering in the Nooksack River Valley, Washington. Huxley College of Environmental Studies. Bellingham, Washington. (Unpublished Problem Series). 26 pp.

Heddleston, K. L. 1972. Fowl cholera. Pages 219-241 *in* M. S. Hofstad, B. W. Calnek, C. F. Helmboldt, W. M. Reid, and H. W. Yoder, Jr., eds. Diseases of poultry, 6th ed. Iowa State Univ. Press, Ames.

Heflebower, C. C. and E. V. Klett. 1980. A killer hailstorm at the Washita Refuge. Bull. Okla. Ornith. Soc. 13:26-28.

Hefley, H. M. 1937. Ecological studies on the Canadian River floodplain in Cleveland County, Oklahoma. Ecol. Monogr. 7:345-402.

Higgins, K. F., and M. A. Johnson. 1978. Avian mortality caused by a September wind and hail storm. Prairie Nat. 10:43-48.

Hopkins, H. H. 1951. Ecology of the native vegetation of the Loess Hills in central Nebraska. Ecol. Monogr. 21:125-147.

Horton, J. S., F. C. Mounts, and J. M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species. U.S. For. Serv. Rocky Mountain Forest and Range Exp. Sta. Pap. 48. 26 pp.

Hosner, J. F. 1958. The effects of complete inundation upon seedlings of six bottomland tree species. Ecology 39:371-373.

Hosner, J. F., and L. S. Minckler. 1963. Bottomland hardwood forests of southern Illinois - regeneration and succession. Ecology 44:29-41.

Hunter, B. F. 1967. Isolation of *Pasteurella multocida* from a snowy owl (*Nyctea scandiaca*), a new host record. Calif. Fish Game 53:213-214.

Hurt, J. 1978. Avian cholera in Nebraska. Wildl. Dis. Assoc. Newsl., July, 1978. p. 1.

Jensen, W. I., J. M. Micuda, R. M. Duncan, and J. P. Allen. 1968. Investigations of the causes and dynamics of avian botulism. Ann. progress rep. for period Jan. - Dec., 1968. U.S. Bur. Sport Fish. Wildl., Denver Wildl. Res. Cent. 15 pp. Unpubl. rep.

Jensen, W. I., and C. S. Williams. 1964. Botulism and fowl cholera. Pages 333-341 *in* J. P. Linduska, ed. Waterfowl tomorrow. U.S. Fish Wildl. Serv., Washington, D.C.

Johnson, W. C., R. L. Burgess, and W. R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecol. Monogr. 46:59-84.

Kalmbach, E. R., and M. F. Gunderson. 1934. Western duck sickness: a form of botulism. U.S. Dep. Agric. Tech. Bull. 411. 81 pp.

Kapustka, L. A. 1972. Germination and establishment of *Populus deltoides* in eastern Nebraska. M.S. Thesis, Univ. Nebraska, Lincoln. 72 pp.

Kellogg, R. S. 1905. Forest belts of western Kansas and Nebraska. U.S. For. Serv. Bull. 66. 44 pp.

Kendeigh, S. C., V. R. Dol'nik, and V. M. Gavrilov. 1977. Avian energetics. Pages 127-204 *in* J. Pinowski and S. C. Kendeigh, eds. Granivorous birds in ecosystems. Cambridge Univ. Press, London, England.

Klukas, R. W., and L. N. Locke. 1970. An outbreak of fowl cholera in Everglades National Park. J. Wildl. Dis. 6:77-79.

Korschgen, C. E., H. C. Gibbs, and H. L. Mendall. 1978. Avian cholera in eider ducks in Maine. J. Wildl. Dis. 14:254-258.

Krapu, G. L. 1979. Nutrition of female dabbling ducks during reproduction. Pages 59-70 *in* T. A. Bookhout, ed. Waterfowl and wetlands - an integrated review. Proc. 1977 Symp., Madison, Wisc., North Central Sect., The Wildl. Soc.

Krapu, G. L. 1981. The role of nutrient reserves in mallard reproduction. Auk. 98:29-38.

Kroonemeyer, K. E. 1978. The U.S. Fish and Wildlife Service's Platte River National Wildlife Study. Pages 29-32 *in* J. C. Lewis, ed. Proc. 1978 Crane Workshop. Natl. Audubon Soc.

Kuck, T. L. 1971. Recovery analysis of mallards banded for justification of the Central Flyway high plains mallard management unit 1969-70. South Dakota Pittman-Robertson Project W-75-R12.

Lahrman, F. W. 1976. Whooping crane sightings in Saskatchewan, 1954-1957 and 1964-1976. Saskatchewan Mus. of Nat. History, Regina. Unpubl. rep.

Lefebvre, E. A., and D. G. Raveling. 1967. Distribution of Canada geese in winter as related to heat loss at varying environmental temperatures. J. Wildl. Manage. 31:538-546.

Leibovitz, L. 1971. Duck plague. Pages 22-33 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds. Infectious and parasitic diseases of wild birds. Iowa State Univ. Press, Ames.

Lewis, J. C. 1974. Ecology of the sandhill crane in the southeastern Central Flyway. Ph.D. Thesis, Oklahoma State Univ., Stillwater. 213 pp.

Lewis, J. C., Chairman. 1977. Sandhill crane (*Grus canadensis*). Pages 5-43 *in* G. C. Sanderson (editor). Management of Migratory Shore and Upland Game Birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C. 358 pp.

Lincer, J. L., W. S. Clark, and M. N. LeFranc, Jr. 1979. Working bibliography of the bald eagle. Nat. Wildl. Fed. Sci. Tech. Ser. 2. 219 pp.

Lish, J. W. 1973. Status and ecology of bald eagles and nesting of golden eagles in Oklahoma. M.S. Thesis, Oklahoma State Univ., Stillwater. 97 pp.

Lish, J. W., and J. Lewis. 1975. Status and ecology of bald eagles wintering in Oklahoma. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29:415-423.

Lock, R. 1972. Population trends of non-game species. Nebraska Game Parks Comm., Lincoln. 7 pp. Unpubl. rep.

Lock, R. 1974. Population surveys of non-game species. Nebraska Game Parks Comm., Lincoln. 10 pp. Unpubl. rep.

Locke, L. N., V. Stotts, and G. Wolfhard. 1970. An outbreak of fowl cholera in waterfowl on the Chesapeake Bay. J. Wildl. Dis. 6:404-407.

Martin, A. C., N. Hotchkiss, F. M. Uhler, and W. S. Bourn. 1953. Classification of wetlands of the United States. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. 20. 14 pp.

Mathisen, J. E., and A. Mathisen. 1968. Species and abundance of diurnal raptors in the panhandle of Nebraska. Wilson Bull. 80: 479-486.

McCallum, D. A., W. D. Graul, and R. Zaccagnini. 1977. The breeding status of the long-billed curlew in Colorado. Auk 94:599-601.

McDougle, H. C., R. Vaught, and H. H. Burgess. 1965. Fowl cholera outbreak in northwest Missouri snow geese. 4 pp. Unpubl. rep.

McLeod, K. W., and J. K. McPherson. 1973. Factors limiting the distribution of *Salix nigra*. Bull. Torrey Bot. Club 100:102-110.

McVaugh, R. 1957. Establishment of vegetation on sand-flats along the Hudson River, New York.--II. The period 1945-1955. Ecology 38:23-29.

Merrill, G. W. 1961. Loss of 1,000 lesser sandhill cranes. Auk 78: 641-642.

Missouri River Basin Commission. 1975. Platte River Basin, Nebraska - Level B Study: Land use and economics. Tech. pap. 144 pp.

Morrison, F. B. 1957. Feeds and feeding. 22nd ed. Morrison Publ., Ithaca, New York. 1165 pp.

Moss, E. H. 1938. Longevity of seed and establishment of seedlings in species of *Populus*. Bot. Gaz. 99:529-542.

Nickel, J. 1978. Origin and plant succession of Platte River islands. Soil analysis and interpretation. Kearney State College, Dep. Biology, Kearney, Nebraska. 20 pp.

Noble, M. G. 1979. The origin of *Populus deltoides* and *Salix interior* zones on point bars along the Minnesota River. Am. Midl. Nat. 102:59-67.

Pearson, G., and W. Jensen. 1972. Waterfowl botulism--a brief summary. U.S. Bur. Sport Fish. Wildl. 16 pp. Unpubl. rep.

Petrides, G. A., and C. R. Bryant. 1951. An analysis of the 1949-50 fowl cholera epizootic in Texas Panhandle waterfowl. Trans. N. Am. Wildl. Conf. 16:193-216.

Proctor, S. J., G. L. Pearson, and L. Leibovitz. 1975. A color atlas of wildlife pathology: 2. Duck plague in free-flying waterfowl observed during the Lake Andes epizootic. Wildl. Dis. 67. 59 pp.

Pursglove, S. R., Jr., D. F. Holland, F. H. Settle and D. C. Gnegy. 1976. Control of a fowl cholera outbreak among coots in Virginia. Proc. Southeastern Conf. Assoc. Fish and Wildl. Agencies 30:602-609.

Quortrup, E. R., F. B. Queen, and L. J. Merovka. 1946. An outbreak of pasteurellosis in wild ducks. J. Am. Vet. Med. Assoc. 108:94-100.

Rand, P. J. 1973. The woody phreatophyte communities of the Republican River Valley in Nebraska. Botany Dep., Univ. of Nebraska, Lincoln. 110 pp.

Raveling, D. G. 1979. The annual cycle of body composition of Canada geese with special reference to control of reproduction. Auk 96:234-252.

Raveling, D. G., W. E. Crews, and W. D. Klimstra. 1972. Activity patterns of Canada geese during winter. Wilson Bull. 84:278-295.

Read, R. A. 1958. Trees for Nebraska windbreaks. Nebr. Farmer 100(7):42.

Reed, L. W. 1971. Use of western Lake Erie by migratory and wintering waterfowl. M.S. Thesis, Michigan State Univ. 71 pp.

Robertson, P. A., G. T. Weaver, and J. A. Cavanaugh. 1978. Vegetation and tree species patterns near the northern terminus of the southern floodplain forest. Ecol. Monogr. 48:249-267.

Rosen, M. N. 1969. Species susceptibility to avian cholera. Bull. Wildl. Dis. Assoc. 5:195-200.

Rosen, M. N. 1971a. Botulism. Pages 100-117 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds. Infectious and parasitic diseases of wild birds. Iowa State Univ. Press, Ames.

Rosen, M. N. 1971b. Avian cholera. Pages 59-74 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds. Infectious and parasitic diseases of wild birds. Iowa State Univ. Press, Ames.

Rosen, M. N. 1972. The 1970-71 avian cholera epornitic's impact on certain species. J. Wildl. Dis. 8:75-78.

Rosen, M. N., and A. I. Bischoff. 1949. The 1948-49 outbreak of fowl cholera in birds in the San Francisco Bay area and surrounding counties. Calif. Fish Game 35:185-192.

Rosen, M. N., and A. I. Bischoff. 1950. The epidemiology of fowl cholera as it occurs in the wild. Trans. N. Am. Wildl. Conf. 15:147-154.

Rosen, M. N., and E. E. Morse. 1959. An interspecies chain in a fowl cholera epizootic. Calif. Fish Game 45:51-56.

Shelford, V. E. 1954. Some lower Mississippi Valley flood plain biotic communities; their age and elevation. Ecology 35:126-142.

Shickley, G. M. 1961. Wintering bald eagles in Nebraska, 1959-1960. Nebr. Bird Rev. 29:26-31.

Shull, C. A. 1944. Observations of general vegetational changes on a river island in the Mississippi River. Am. Midl. Nat. 32:771-776.

Sibbald, I. R. 1979. Bioavailable amino acids and true metabolizable energy of cereal grains. Poultry Sci. 58:934-939.

Siniff, D. B., and J. R. Tester. 1965. Computer analysis of animal movement data obtained by telemetry. Bioscience 15:104-108.

Steenhof, K. 1976. The ecology of wintering bald eagles in southeastern South Dakota. M.S. Thesis, Univ. Missouri, Columbia. 148 pp.

Swenk, M. H. 1933. The present status of the whooping crane. Nebr. Bird Rev. 1:111-129.

U.S. Bureau of Sport Fisheries and Wildlife. 1973. Threatened wildlife of the United States. 1973 ed. U.S. Bur. Sport Fish. Wildl. Resour. Publ. 114. 289 pp.

U.S. Environmental Data Service. 1959-1980. Storm data. Vol. 1-22.

U.S. Environmental Data Service. 1978-1980. Climatological data, Nebraska. Vol. 83-85.

Vaught, R. W., H. C. McDougle, and H. H. Burgess. 1967. Fowl cholera in waterfowl at Squaw Creek National Wildlife Refuge, Missouri. J. Wildl. Manage. 31:248-253.

Vian, W. E. 1971. The wintering bald eagle (*Haliaeetus leucocephalus*) on the Platte River in southcentral Nebraska. M.S. Thesis, Kearney State College, Kearney, Nebraska. 60 pp.

Vian, W. E., and J. C. W. Bliese. 1974. Observations on population changes and on behavior of the bald eagle in southcentral Nebraska. Nebr. Bird Rev. 42:46-55.

Walkinshaw, L. H. 1956. Two visits to the Platte Rivers and their sandhill crane migration. Nebr. Bird Rev. 24:18-21.

Wallenstrom, R. L. 1976. The Platte River National Wildlife Refuge. Pages 141-143 *in* J. C. Lewis, ed. Proc. Int. Crane Workshop. Oklahoma State Univ.

Ware, G. H., and W. T. Penfound. 1949. The vegetation of the lower levels of the floodplain of the South Canadian River in central Oklahoma. Ecology 30:478-484.

Weaver, J. E. 1960. Flood plain vegetation of the central Missouri Valley and contacts of woodland with prairie. Ecol. Monogr. 30:37-64.

Wells, P. V. 1970. Vegetational history of the Great Plains: A post-glacial record of coniferous woodland in southeastern Wyoming. Pages 185-202 *in* W. Dort and J. K. Jones, eds. Pleistocene and recent environments of the central Great Plains. Univ. Kansas Press, Lawrence.

Wheeler, R. H. and J. C. Lewis. 1972. Trapping techniques for sandhill crane studies in the Platte River Valley. U.S. Fish Wildl. Serv. Resour. Publ. 107. 19 pp.

Williams, G. P. 1978. The case of the shrinking channels - the North Platte and Platte Rivers in Nebraska. U.S. Geol. Surv. Circ. 781. 48 pp.

Wilson, R. E. 1970. Succession in stands of *Populus deltoides* along the Missouri River in southeastern South Dakota. Am. Midl. Nat. 83:330-342.

Wobeser, G., D. B. Hunter, B. Wright, D. J. Nieman, and R. Isbister. 1979. Avian cholera in waterfowl in Saskatchewan, Spring 1977. J. Wildl. Dis. 15:19-24.

Wright, H. E. 1970. Vegetational history of the central plains. Pages 157-172 *in* W. Dort and J. K. Jones, eds. Pleistocene and recent environments of the central Great Plains. Univ. Kansas Press, Lawrence.

Zinkl, J. G., J. M. Hyland, and J. J. Hurt. 1977a. Aspergillosis in common crows in Nebraska, 1974. J. Wildl. Dis. 13:191-193.

Zinkl, J. G., N. Dey, J. M. Hyland, J. J. Hurt, and K. L. Heddleston. 1977b. An epornitic of avian cholera in waterfowl and common crows in Phelps County, Nebraska, in the spring, 1975. J. Wildl. Dis. 13:194-198.

APPENDICES

Appendix A. Common and scientific names of animals identified in the Platte River Ecology Study summary report.

Common name	Scientific name
American Coot[a]	*Fulica americana*
American Goldfinch	*Carduelis tristis*
American Green-winged Teal	*Anas crecca carolinesis*
American Kestrel	*Falco sparverius*
American Robin	*Turdus migratorius*
American Wigeon	*Anas americana*
Bald Eagle	*Haliaeetus leucocephalus*
Bank Swallow	*Riparia riparia*
Barn Owl	*Tyto alba*
Barn Swallow	*Hirundo rustica*
Bell's Vireo	*Vireo bellii*
Belted Kingfisher	*Megaceryle alcyon*
Bewick's Wren	*Thryomanes bewickii*
Black-capped Chickadee	*Parus atricapillus*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Blacktail Jackrabbit[b]	*Lepus californicus*
Blacktail Prairie Dog	*Cynomys ludovicianus*
Blue Grosbeak	*Guiraca caerulea*
Blue Jay	*Cyanocitta cristata*
Blue-winged Teal	*Anas discors*
Boblink	*Dolichonyx oryzivorous*
Bobwhite	*Colinus virginianus*

(continued)

Appendix A. (Continued).

Brewer's Sparrow	*Spizella breweri*
Brown-headed Cowbird	*Molothrus ater*
Brown Thrasher	*Toxostoma rufum*
Burrowing Owl	*Athene cunicularia*
Canada Goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Cardinal	*Cardinalis cardinalis*
Carp[c]	*Cyprinus carpio*
Cassin's Sparrow	*Aimophila cassinii*
Catfish	*Ictalurus* sp.
Chestnut-collared Longspur	*Calcarius ornatus*
Chimney Swift	*Chaetura pelagica*
Cliff Swallow	*Petrochelidon pyrrhonota*
Common Eider	*Somateria mollissima*
Common Flicker	*Colaptes auratus*
Common Grackle	*Quiscalus quiscula*
Common Merganser	*Mergus merganser*
Common Nighthawk	*Chordeiles minor*
Common Yellowthroat	*Geothlypis trichas*
Cooper's Hawk	*Accipiter cooperii*
Deer Mouse	*Peromyscus maniculatus*
Dickcissel	*Spiza americana*
Downy Woodpecker	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis*
Eastern Cottontail	*Sylvilagus floridanus*

(continued)

Appendix A. (Continued).

Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Eastern Phoebe	*Sayornis phoebe*
Eastern Wood Pewee	*Contopus virens*
Ferruginous Hawk	*Buteo regalis*
Field Sparrow	*Spizella pusilla*
Fox Squirrel	*Sciurus niger*
Gizzard Shad	*Dorosoma cepedianum*
Grasshopper Mouse	*Onychomys leucogaster*
Grasshopper Sparrow	*Ammodramus savannarum*
Gray Catbird	*Dumetella carolinensis*
Great Crested Flycatcher	*Myiarchus crinitus*
Greater Scaup	*Aythya marila*
Greater Prairie Chicken	*Tympanuchus cupido*
Great Horned Owl	*Bubo virginianus*
Golden Eagle	*Aquila chrysaetos*
Goshawk	*Accipiter gentilis*
Hairy Woodpecker	*Picoides villosos*
Horned Lark	*Eremophila alpestris*
House Sparrow	*Passer domesticus*
House Wren	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferous*
Lark Bunting	*Calamospiza melanocorys*
Lark Sparrow	*Chondestes grammacus*

(continued)

Appendix A. (Continued).

Lazuli Bunting	*Passerina amoena*
Least Tern	*Sterna albifrons*
Lesser Scaup	*Aythya affinis*
Lesser Snow Goose	*Chen caerulescens*
Loggerhead Shrike	*Lanius ludovicianus*
Long-billed Curlew	*Numenius americanus*
Mallard	*Anas platyrhynchos*
Marsh Hawk	*Circus cyaneus*
Meadow Vole	*Microtus pennsylvanicus*
Merlin	*Falco columbarius*
Mourning Dove	*Zenaida macroura*
Mule Deer	*Odocoileus hemionus*
Muskrat	*Ondatra zibethica*
Northern Oriole	*Icterus galbula*
Northern Shoveler	*Anas clypeata*
Orchard Oriole	*Icterus spurius*
Peregrine Falcon	*Falco peregrinus*
Pintail	*Anas acuta*
Piping Plover	*Charadrius melodus*
Plains Pocket Gopher	*Geomys bursarius*
Prairie Falcon	*Falco mexicanus*
Pronghorn	*Antilocapra americana*
Quillback Carpsucker	*Carpiodes cyprinus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Red-eyed Vireo	*Vireo olivaceus*

(continued)

Appendix A. (Continued).

Redhead	*Aythya americana*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Redhorse	*Moxostoma* sp.
Red-tailed Hawk	*Buteo jamaicensis*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-necked Pheasant	*Phasianus colchicus*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Rough-legged Hawk	*Buteo lagopus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Sandhill Crane	*Grus canadensis*
Screech Owl	*Otus asio*
Sharp-shinned Hawk	*Accipiter striatus*
Sharp-tailed Grouse	*Pedioecetes phasianellus*
Short-eared Owl	*Asio flammeus*
Shrew	Family Soricidae
Song Sparrow	*Melospiza melodia*
Spotted Sandpiper	*Actitis macularia*
Starling	*Sturnus vulgaris*
Swainson's Hawk	*Buteo swainsoni*
Upland Sandpiper	*Bartramia longicauda*
Vesper Sparrow	*Pooecetes gramineus*
Warbling Vireo	*Vireo gilvus*
Western Kingbird	*Tyrannus verticalis*
Western Meadowlark	*Sturnella neglecta*
Western Wood Pewee	*Contopus sordidulus*

(continued)

Appendix A. (Continued).

White-footed Mouse	*Peromyscus leucopus*
White-fronted Goose	*Anser albifrons*
Whitetail Deer	*Odocoileus virginianus*
Whooping Crane	*Grus americana*
Willow Flycatcher	*Empidonax traillii*
Wilson's Phalarope	*Steganopus tricolor*
Yellow Warbler	*Dendroica petechia*
Yellow-billed Cuckoo	*Coccyzus americanus*

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[a] Common and scientific names of birds follow American Ornithologist's Union (1957, 1976).

[b] Common and scientific names of mammals follow Hall and Kelson (1959).

[c] Common and scientific names of fishes follow American Fisheries Society (1970).

Appendix B. Common and scientific names of the major plant species on the Platte River floodplain.

Common name	Scientific name
Alfalfa	*Medicago sativa*
American Bugleweed	*Lycopus americanus* Muhl.
American Bulrush	*Scirpus americanus* Pers.
American Elm	*Ulmus americana* L.
American Germander	*Teucrim canadense*
Aster	*Aster* sp.
Barnyard Grass	*Echinochloa crus-galli* (L.) Beauv.
Big Bluestem	*Andropogon gerardi* Vitman
Black-eyed Susan	*Rudbeckia hirta*
Black Locust	*Robinia pseudoacacia* L.
Black Walnut	*Juglans nigra* L.
Blazing Star	*Liatris punctata*
Blue Grama	*Bouteloua gracilis*
Bluegrass	*Poa pratensis* L.
Box Elder	*Acer negundo* L.
Buckbrush	*Symphoricarpos orbiculatus* Moench
Buffalo Grass	*Buchloe dactyloides*
Buffaloberry	*Shepherdia argentea* (Pursh) Nutt.
Bundleflower	*Desmanthus illinoensis* (Michx.) MacM.
Canada Goldenrod	*Solidago canadensis* L.
Canada Sanicle	*Sanicula canadensis* L.
Canada Wild Rye	*Elymus canadensis* L.

(continued)

Appendix B. (Continued).

Catalpa	*Catalpa speciosa* Warder
Cattail	*Typha latifolia* L.
Cheatgrass	*Bromus tectorum* L.
Chinese Elm	*Ulmus parvifolia* Jacaq.
Choke Cherry	*Prunus virginiana* L.
Climbing Bittersweet	*Cleastrus scandens* L.
Cocklebur	*Xanthium strumarium* L.
Common Mullein	*Verbascum thapsus* L.
Common Ragweed	*Ambrosia artemisiifolia* L.
Cone Flower	*Ratibida columnarius*
Corn	*Zea mays*
Cottonwood	*Populus deltoides* Marsh.
Dandelion	*Taraxacum officinale* Weber
Diamond Willow	*Salix rigida* Muhl.
Foxtail Barley	*Hordeum jubatum* L.
Fringed Loosestrife	*Lysimachia ciliata*
Frog Fruit	*Phyla lanceolata* (Michx.) Greene
Green Ash	*Fraxinus pennsylvanica* Marsh.
Ground Cherry	*Physalis virginiana* Mill.
Hackberry	*Celtis occidentalis* L.
Hairy Grama	*Bouteloua hirsuta* Lag.
Hardstem Bulrush	*Scirpus acutus* Muhl.
Hoary Vervain	*Verbena stricta* Vent.
Hopseed	*Medicago lupulina* L.
Indian Grass	*Sorghastrum avenaceum* (Michx.) Nash

(continued)

Appendix B. (Continued).

Indigo Bush	*Amorpha fruticosa* L.
Ironweed	*Vernonia fasciculata* Michx.
Japanese Brome	*Bromus japonicus* Thunb.
Junegrass	*Koeleria cristata*
Lady's Thumb Smartweed	*Polygonum persicaria* L.
Lead Plant	*Amorpha canescens*
Little Bluestem	*Andropogon scoparius* Michx.
Loosestrife	*Lythrum dacotanum* Nieuw.
Lovegrass	*Eragrostis pectinacea* (Michx.) Ness
Milo	*Sorghum* sp.
Needle and Thread	*Stipa comata* Trin. & Rupr.
Needle-leaf Sedge	*Carex eleocharis*
Nutsedge	*Cyperus* sp. (including: *C. erythrorhizos*, *C. esculeutus*)
Osage Orange	*Maclura pomifera* (Raf.) Schneid.
Pale Smartweed	*Polygonum lapathifolium* L.
Peach-leaf Willow	*Salix amygdaloides* Anderss.
Plains Muhly	*Muhlenbergia cuspidata*
Plains Sunflower	*Helianthus petiolarus* Nutt.
Poison Ivy	*Rhus radicans* (L.) O. Ktze.
Prairie Cordgrass	*Spartina pectinata* Link
Prairie Dogbane	*Apocynum sibiricum* Jacqy.
Prickly Ash	*Zanthoxylum americanum* Mill.
Red Cedar	*Juniperus virginiana* L.
Red Clover	*Trifolium pratense* L.

(continued)

Appendix B. (Continued).

Red Mulberry	*Morus rubra* L.
Red-osier Dogwood	*Cornus stolonifera* Michx.
Redtop	*Agrostis stolonifera* L.
Reed Canary Grass	*Phalaris arundinacea* L.
Rough-leaf Dogwood	*Cornus drummondii* C. A. Meyer
Russian Olive	*Elaeagnus angustifolia* L.
Salt Cedar	*Tamarix ramosissima* Ledeb.
Saltgrass	*Distichlis spicata* (L.) Greene
Sandbar Willow	*Salix exigua* Nutt.
Sand Dropseed	*Sporobolus cryptandrus* (Torr.) Gray
Scarlet Gaura	*Gaura coccinea*
Sedges	Carex sp. (including: *C. atherodes, C. meadii, C. blanda, C. stipata, C. brevior, C. tenera, C. lanuginosa, C. vulpinoidea)*
Siberian Elm	*Ulmus pumila* L.
Side Oats Grama	*Bouteloua curtipendula* (Michx.) Torr.
Silver Maple	*Acer saccharinum* L.
Six-week Fescue	*Festuca octoflora*
Skelton Weed	*Lygodesmia juncea*
Skunkbush	*Rhus aromatica* Ait.
Slippery Elm	*Ulmus rubra* Muhl.
Small Panic Grass	*Panicum oligosanthes* Schult.
Smooth Brome	*Bromus inermis* Leyss.
Smooth Sumac	*Rhus glabra* L.
Snowberry	*Symphoricarpos orbiculatus* Moench

(continued)

Appendix B. (Continued).

Snow-on-the-Mountain	*Euphorbia marginata* Pursh
Spikenard	*Aralia racemosa* L.
Spikerush	*Eleocharis palustris* (L.) R. & S.
Spotted Spurge	*Euphorbia maculata* L.
Switchgrass	*Panicum virgatum* L.
Virginia Creeper	*Parthenocissus vitacea* (Kneer) Hitchc.
Water Sedge	*Carex aquatilis* Wahl.
Western Wheatgrass	*Agropyron smithii*
Wheatgrass	*Agropyron* sp.
White Sweet Clover	*Melilotus albus* Desr.
Wild Alfalfa	*Psoralea tenuiflora*
Wild Grape	*Vitis riparia* Michx.
Wild Plum	*Prunus americana* Marsh.
Wild Rose	*Rosa woodsii* Lindl.
Woodbine	*Parthenocissus vitacea* (Knerr) Hitchc.

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[a] Common and scientific names follow Great Plains Flora Association (1977).

Appendix C. Locations of confirmed whooping crane sightings on or near the Platte River, 1912-49.[a] County of sighting is listed in parentheses.

Date	Location and number of birds
Spring 1912	2 adults shot on Platte River; north of Prosser (Hall)
29 March 1919	Small flock seen on an island in the Platte River in a large flock of sandhill cranes; near Kearney (Buffalo)
7 October 1920	2 seen on the Platte River; near Kearney (Buffalo)
10 October 1920	10 seen on the Platte River; near Kearney (Buffalo)
15 October 1920	3 seen on the Platte River; near Kearney (Buffalo)
1-5 May 1922	7 seen on Platte River (near Golary farm); near Kearney (Buffalo)
13 April 1924	Flock of 11 seen flying from the Platte River at close range and starting northwest; just west of Kearney (Buffalo)
16 October 1924	4 seen on the Platte River; just east of bridge at Kearney (Buffalo)
7 April 1925	3 seen alighting on (sand) bar in Platte River south of A. R. Golay home; near Kearney (Buffalo)
19 October 1925	1 seen flying high and circling toward the east; just east of bridge at Kearney (Buffalo)
25 October 1925	5 seen flying west along the Platte River; a few miles west of Odessa (Buffalo)
25 October 1925	5 seen on a sandbar in the Platte River (3 adults, 2 juveniles); west of bridge at Overton (Dawson)
4 April 1926	2 seen along Platte River; 5 miles west of Kearney (Buffalo)
4 April 1926	2 seen and heard calling in close company in a large flock of sandhill cranes flying west from Platte River bridge (probably were the same birds as the preceding); just south of Kearney (Buffalo)
7 April 1926	6 seen resting on a sandbar in the Platte River among a large flock of sandhill cranes (2 showed traces of the reddish brown immature plumage); 4 miles west of Kearney (Buffalo)

(continued)

Appendix C. (Continued).

8 April 1926	5 seen feeding in meadow near observer's house. After feeding for a time they flew to the Platte River; just west of bridge at Kearney.
18 April 1926	1 lone bird on the Platte River; near Odessa (Buffalo)
22 September 1928	Seen flying up the Platte River; near Newark (Kearney)
24 October 1928	5 seen flying up the south bank of the Platte River, calling, and later 3 flew directly over the observer; near Newark (Kearney)
13 October 1929	1 lone bird seen standing on a sandbar in the Platte River; just west of Kearney (Buffalo)
3 April 1930	3 seen standing on a sandbar in the Platte River in company with a large flock of sandhill cranes; 1 mile west of Kearney (Buffalo)
3 April 1930	8 in a flock on the river, alone; 2 miles east of Kearney (Buffalo)
25 October 1931	7 adults and 2 immatures on Platte River just east of Elm Creek (Buffalo)
3 April 1931	3 seen along the Platte River; Kearney (Buffalo)
May 1934	2 seen along the Platte River; Wood River (Hall)
1 April 1936	7 seen flying over Platte River; Cozad (Dawson)
17 April 1939	5 seen along Platte River; between Cozad and Darr (Dawson)
22 October 1942	1 bird seen along Platte River; Odessa (Buffalo)
2 April 1944	3 seen in Platte River; near Kearney (Buffalo)
19 April 1948	5 seen (4 adults, 1 juvenile) on a sandbar in the South Platte River due south of the airport at North Platte (Lincoln)

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[a] This list includes only those sightings for which a reasonably specific location at or near the river was given. Data originally published in Swenk (1933) and Brooking (1943a, 1943b, 1944); only those listed as confirmed by Allen (1952) are included in this list.

Appendix D. Characteristics of the Platte River at sites known to have been used by whooping cranes.

Sighting location and date	Activity of cranes	Width of river	Depth of river	Horizontal visibility	Overhead visibility	Aquatic vegetation	Presence of sandbars in river	Type of sandbars	Isolation	Bottom material	Distance to feeding site
21-22 October 1966 6 mi. N.E. of Phillips	roosting, loafing	approx. 250 m	maximum of 46 cm	bank-to-bank and unlimited upstream and downstream	good	none	yes	low, 1-2° slopes, devoid of vegetation	Chapman Bridge visible; both banks lined with tall trees; hunting blinds in channel	moving sand and some small gravel	5 miles to the S.W.
31 October - 1 November 1974 2 mi. E. of Minden I-80 interchange	roosting, probing, flying up and down river	approx. 260 m	approx. 2.5-10 cm at roost site, channel deeper	bank-to-bank in most places, but limited locally by some vegetated sandbars; good upstream and downstream	good, but possibly limited locally by indigo-bush on some sandbars	none	yes	some are low, 1-2° slopes, and devoid of vegetation; others have shrubs and banks	I-80 audible to the north; tall vegetation on both banks; hunting blinds in channel	moving sand and some small gravel	foraged in river; flew 1/2 - 1 mile to field to the south
17 April 1980 4 1/2 mi. S. and 1/2 mi. W. of Gibbon	loafing	135-185 m	0.6-0.8 m deep where cranes were loafing	probably bank-to-bank and very good both upstream and downstream	good, but possibly limited locally by small willows on sandbars	none	yes - occasional bars in this stretch of the river	small, covered with willows	channel lined with occasional cottonwoods; commercial sand and gravel operation 1/4 mi. E.; site surroundings owned by NAS	moving sand and gravel	approx. 2 miles; 1 mile to the south
18 April 1980 5 1/2 mi. S. and 5 mi. W. of Gibbon	probably overnight roosting; also loafing, preening, dancing and probing	approx. 185 m	46-51 cm in channel cranes in shallower water at edge of sandbar	probably bank-to-bank in most places and very good upstream and downstream	good, but possibly limited locally by small willows and some sandbars	none	yes - several sandbars in area	sandbars are low (2-3" high) and devoid of vegetation - some vegetated sandbars nearby	willows and scattered cottonwoods on bank; bridge visible to the west	moving sand and gravel	probed in river

Appendix E. Distribution and abundance of wintering mallards (upper value) and geese (lower value) along the North Platte and Platte Rivers.

River section	Date 14 Dec. 1978	17 Jan. 1979	16 Feb. 1979	30 Nov. 1979	14 Dec. 1979	8 Jan. 1980	21 Jan. 1980	1 Feb. 1980
Kingsley Dam - Keystone bridge	0	50	0	0	2	-	690	250
	0	0	200	0	0	-	0	150
Keystone bridge - Paxton bridge	0	40	56	0	24	-	46	34
	0	108	0	0	18	-	0	0
Paxton bridge - Sutherland bridge	120	50	0	198	0	-	91	39
	0	0	0	0	2	-	0	0
Sutherland bridge - Hershey bridge	80	0	0	60	0	-	0	0
	0	0	0	0	0	-	0	0
Hershey bridge - U.S. 83 bridge	0	0	0	0	16	-	3	20
	0	0	0	0	0	-	5	11
U.S. 83 bridge - Maxwell bridge	0	208	0	4	46	255	132	54
	0	0	25	0	0	0	0	0
Maxwell bridge - Brady bridge	15	20	20	69	0	8	225	3
	0	0	0	0	0	0	0	0
Brady bridge - State Hwy. 47 bridge	5	13	0	0	0	0	0	0
	50	0	0	0	0	0	0	0
State Hwy. 47 bridge - State Hwy. 21 bridge	0	36	305	0	154	210	15	180
	0	0	0	0	0	0	0	0

(continued)

Appendix E. (Continued).

State Hwy. 21 bridge - Darr bridge	550	425	0	13	20	25	40	30
	0	0	0	0	0	0	0	0
Darr bridge - U.S. 283 bridge	150	15	3	0	40	700	210	129
	0	0	0	0	0	0	0	0
U.S. 283 bridge - Overton bridge	230	130	47	0	1,933	23,655	8,437	4,067
	0	0	2,900	0	0	240	1,210	1,735
Overton bridge - U.S. 183 bridge	1,300	2,580	2,100	25	0	1,593	1,726	328
	100	80	3,600	69	40	60	0	0
U.S. 183 bridge - Odessa bridge	1,000	431	3	77	0	20	2,200	96
	100	30	0	50	0	30	0	0
Odessa bridge - State Hwy. 44 bridge	40	36	0	0	50	645	457	1,082
	40	0	0	0	0	10	0	0
State Hwy. 44 bridge - State Hwy. 10 bridge	450	415	100	20	0	2,238	1,656	2,101
	25	44	765	0	0	60	165	800
State Hwy. 10 bridge - Gibbon bridge	200	336	400	0	2,795	1,057	3,247	23
	30	275	0	30	300	60	1,000	40
Gibbon bridge - Shelton bridge	340	175	0	2,039	0	34	2,503	523
	70	150	0	0	0	24	0	0
Shelton bridge - Wood River bridge	10	57	0	40	0	1	135	6
	5	40	55	10	0	40	0	0
Wood River bridge - Alda bridge	70	0	0	15	0	3	1,763	0
	0	35	0	0	0	0	700	0
Alda bridge - U.S. 281 bridge	60	0	0	0	0	3	0	0
	20	0	0	0	0	0	3	0

(continued)

Appendix E. (Continued).

U.S. 281 bridge - U.S. 34 bridge	0	0	0	12	0	0	0	0
	0	0	0	0	0	0	0	0
U.S. 34 bridge - Chapman bridge	20	0	25	70	0	80	26	10
	0	0	0	0	0	0	0	0

Appendix F. Mean numbers of raptors seen per census along each survey route in the Platte and North Platte River Valleys during 1979 (upper value) and 1980 (lower value).[a]

Species	Route[b]					
	1	2	3	4	5	6
Rough-legged Hawk	1.0	1.1	2.1	0.8	1.3	2.3
	2.0	0.3	0.5	0.5	0.8	5.3
Ferruginous Hawk	0.1	0.0	0.2	0.1	0.4	0.6
	0.0	0.0	0.0	0.5	0.3	0.0
Red-tailed Hawk	5.7	4.1	6.3	3.9	4.0	4.7
	3.5	2.3	4.3	3.5	4.3	3.5
Golden Eagle	0.1	0.2	0.4	0.1	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Bald Eagle	0.4	1.2	7.6	11.2	1.4	0.2
	0.3	1.5	8.8	14.0	1.3	0.3
Prairie Falcon	0.3	0.7	0.7	0.4	1.7	1.1
	1.3	0.5	0.3	0.5	0.5	0.3
American Kestrel	2.9	5.2	3.9	4.7	9.1	4.6
	3.8	5.0	2.3	3.8	10.0	3.0
Marsh Hawk	0.2	0.8	5.3	2.3	2.1	1.6
	0.8	0.0	0.8	0.0	0.0	0.0
Goshawk	0.0	0.0	0.0	0.0	0.1	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Cooper's Hawk	0.0	0.0	0.0	0.0	0.1	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Sharp-shinned Hawk	0.0	0.2	0.2	0.0	0.4	0.1
	0.0	0.3	0.0	0.3	1.0	0.0
Great Horned Owl	0.1	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.3

[a] Based on nine censuses per route in 1979 and four censuses per route in 1980.

[b] Approximate route locations are as follows:

(continued)

Appendix F. (Continued).

Route 1 - 1 mile northwest of the US 34 highway bridge westward to the Alda bridge.

Route 2 - Wood River bridge westward to about 1.5 miles west of the Gibbon road.

Route 3 - Kearney bridge westward to the Overton bridge.

Route 4 - 0.5 mile west of the Overton bridge westward to the Darr bridge.

Route 5 - Gothenburg bridge westward to the Maxwell bridge.

Route 6 - 0.5 mile west of highway 83 westward to Sutherland (along the North Platte River).

Appendix G. Location and characteristics of bald eagle nocturnal roosts and the mean number of eagles censused per roost.

Roost	Legal description	County	Ownership	Area (ha)	Distance (km) to nearest					Habitat	Mean no. of bald eagles
					River	Dwelling	Road	I-80	Railroad		
A	SE 1/4, SE 1/4, Sec 31, T16N, R14W	Garden	Leased to State	1.2	0.5	1.3	0.4	>2.4	0.8	Shelterbelt	20.9
B_1	SE 1/4, SE 1/4, Sec 26, T15N, R38W	Keith	Private	1.9	2.6	0.8	0.6	>2.4	>1.6	Tree Claim	15.0
B_2	NE 1/4, Sec 30, T15N, R38W	Keith	Private	3.6	3.2	0.4	0.3	>2.4	0.1	Tree Claim	2.0[a]
C	SW 1/4, SE 1/4, Sec 10, T13N, R29W	Lincoln	Private	1.3	0	1.0	0.3	2.3	0.3	Tree Claim	12.4
D	SW 1/4, NE 1/4, Sec 29, T12N, R26W	Lincoln	Private	0.9	0	1.2	0.8	0.8	>1.6	Riparian Woodland	8.0
F	SE 1/4, SE 1/4, Sec 15, T9N, R22W	Dawson	Private	0.9	0.2	0.7	0.5	1.6	>1.6	Riparian Woodland	7.9
F_1	SE 1/4, Sec 6, T8N, R20W	Dawson	Private	1.5	0.2	0.4	0.4	1.5	>1.6	Tree Claim	6.7
F_2	NW 1/4, Sec 9, T8N, R20W	Dawson	Private	1.1	0	0.8	1.2	1.6	>1.6	Riparian Woodland	5.2[a]
F_3	NE 1/4, Sec 10, T8N, R20W	Dawson	Private	0.8	0	0.8	0.8	1.6	>1.6	Riparian Woodland	13.2[a]
G	NE 1/4, Sec 9, T8N, R19W	Dawson	Private	2.1	0	1.0	1.1	1.3	>1.6	Riparian Woodland	27.1
H	NW 1/4, NE 1/4, Sec 8, T8N, R14W	Buffalo	Private	3.0	0.2	0.7	0.5	0.5	>1.6	Tree Claim	9.3

[a] Censused in 1980 only.

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Appendix H. Prey items identified from egested pellets of bald eagles at roost sites in the North Platte and Platte River Valleys in Nebraska. (Only those items occurring in more than 1% of the collected pellets are included).

Invertebrates

- crayfish

Fishes

- gizzard shad
- carp
- quillback carpsucker
- redhorse
- catfish, unident.

Birds

- Canada goose
- mallard
- pintail
- green-winged teal
- common merganser
- buteo, unident.
- greater prairie chicken
- ring-necked pheasant
- American coot
- western meadowlark

Mammals

- shrew, unident.
- blacktail prairie dog
- fox squirrel
- plains pocket gopher
- white-footed or deer mouse
- grasshopper mouse
- meadow vole
- muskrat
- blacktail jackrabbit
- eastern cottontail
- pronghorn
- deer (mule and whitetail)
- domestic sheep
- domestic cattle

Appendix I. Characteristics of river segments within sandhill crane staging areas[a].

ID	AREA	ROAD	BRIDGE	WIDTH	CHANNOW	BANKBANK	AREANOW	HTBANK	HTNORTH	HTSOUTH	I1	I2	I3	I4	I5	CRANES
24	1	0	0	164	268	543	55.3	4	5	5	1.6	5.6	12.0	8.9	21.4	0
25	1	0	0	140	292	591	39.0	2	1	5	1.9	14.1	0.3	26.9	2.5	0
26	1	0	0	153	213	281	42.6	2	5	5	0.7	8.1	0.0	0.9	1.5	700
27	1	0	0	183	208	294	41.8	5	5	1	0.3	2.0	0.1	0.1	13.1	10,000
28	1	0	0	220	221	258	37.3	2	5	1	0.8	3.5	0.0	0.0	2.8	5,000
29	1	0	0	159	214	300	31.7	2	1	1	0.4	20.7	0.0	2.5	0.0	8,000
30	1	1	1	177	177	177	33.7	2	5	1	0.6	2.7	0.0	0.9	0.0	2,000
31	1	1	1	181	153	153	29.2	1	1	1	0.1	0.0	0.0	0.0	0.0	1,500
32	1	0	0	146	153	220	28.4	2	1	1	0.7	6.7	1.5	0.0	0.0	4,000
33	1	0	0	177	170	247	31.0	2	2	1	0.5	12.0	0.0	0.0	0.0	3,000
34	1	1	1	166	104	104	40.0	2	1	1	0.0	2.3	0.0	0.0	0.0	2,500
35	1	1	1	196	115	115	31.5	2	5	1	0.3	1.1	0.0	0.0	0.0	5,000
36	1	1	1	194	200	212	30.6	2	5	5	0.0	1.1	0.2	0.0	1.5	1,000
37	1	0	0	163	154	331	37.9	3	5	5	1.2	2.3	5.7	0.0	15.8	6,000
38	1	0	0	171	209	234	41.7	2	5	4	1.7	3.0	2.5	0.0	0.0	5,000
39	1	0	0	216	250	330	49.7	3	1	4	0.9	3.6	5.1	0.0	0.0	4,500
40	1	0	0	196	193	257	41.3	3	4	2	1.0	4.2	4.9	0.0	0.0	5,000
41	1	0	0	200	225	319	37.5	3	3	5	2.2	1.5	6.8	0.0	1.0	7,000
42	1	0	0	214	170	297	48.0	3	1	1	0.5	0.5	6.3	1.7	4.1	6,500
43	1	0	0	254	195	250	39.0	3	4	5	0.9	0.4	3.9	0.8	0.0	5,000
44	1	0	0	213	213	213	36.6	4	4	1	0.2	0.1	0.6	3.5	3.1	6,000
45	1	0	0	316	189	189	47.9	2	1	3	0.2	1.3	0.3	0.0	0.0	11,000
46	1	0	0	248	300	367	59.2	2	1	3	1.2	4.3	3.1	2.0	0.0	1,200
47	1	0	0	236	244	250	59.6	2	3	1	0.7	1.8	0.8	0.0	0.0	3,000
48	1	1	1	223	196	227	29.4	3	5	5	0.3	0.2	0.9	0.6	0.0	1,900
49	1	1	1	248	251	308	44.8	4	4	5	0.5	1.6	2.8	3.0	2.1	1,000
50	1	0	0	235	281	408	59.5	3	4	5	4.1	0.9	13.9	3.4	3.2	5,000
51	1	0	0	194	334	461	62.1	3	1	5	1.6	6.2	11.4	11.7	1.6	7,000
52	1	0	0	218	318	399	47.9	4	1	3	0.5	0.2	0.6	9.3	9.8	9,000
53	1	0	0	187	257	384	54.1	4	5	3	0.2	1.1	4.0	6.5	20.3	7,000
54	1	0	0	157	226	378	42.3	5	5	5	0.5	0.3	0.0	5.6	28.3	3,000
55	1	0	0	284	197	197	45.0	2	2	5	0.3	2.1	1.1	3.3	0.9	1,400

(continued)

Appendix I. (Continued).

56	1	0	0	195	146	189	35.6	2	2	5	1.3	3.3	0.0	0.0	0.3	0
57	1	0	0	160	192	231	37.4	2	5	5	1.8	3.3	0.0	0.2	0.0	50
58	1	0	0	207	162	276	37.5	2	1	5	1.5	11.9	2.8	0.0	0.0	500
59	1	1	1	183	145	245	27.9	5	5	5	0.9	5.9	0.1	2.5	6.6	0
60	1	0	0	140	205	562	37.4	5	5	5	1.0	4.2	2.7	10.7	39.8	1,200
61	1	0	0	148	154	485	32.1	5	5	5	2.2	7.8	2.8	4.3	37.6	2,500
62	1	0	0	169	176	306	32.9	4	5	5	1.7	4.5	0.8	3.6	21.6	3,000
63	1	0	0	140	288	483	44.8	2	5	5	2.6	16.8	1.8	11.8	4.2	3,500
64	1	0	0	275	251	433	51.4	5	5	5	4.3	1.5	4.4	4.1	21.0	5,000
65	1	0	0	226	271	591	52.7	5	5	5	1.9	0.8	1.6	0.6	44.9	6,000
66	1	0	0	195	254	293	46.9	3	5	5	1.1	3.5	18.6	0.4	5.9	2,000
67	1	0	0	133	292	512	44.8	5	5	5	1.9	2.2	11.5	0.0	39.8	4,500
68	1	0	0	109	226	787	44.3	5	5	5	0.1	2.4	4.1	2.5	103.4	800
69	1	1	0	129	233	927	41.9	5	2	5	5.1	5.3	0.0	0.0	122.3	0
70	1	1	0	117	249	879	55.4	5	2	5	3.2	3.2	19.1	0.4	111.2	0
71	1	0	0	146	217	503	42.7	5	2	5	2.3	0.2	8.2	0.2	42.1	0
72	1	0	0	178	216	466	41.2	5	5	5	0.7	1.9	1.0	0.0	52.0	0
73	1	1	0	118	225	616	48.7	5	2	5	4.5	3.2	0.6	2.0	69.0	0
74	1	0	0	117	203	890	38.5	5	5	2	0.2	0.3	6.0	0.1	130.4	0
75	1	0	1	240	252	722	63.1	5	5	5	0.1	0.7	1.7	11.3	65.5	0
76	1	1	1	253	306	337	51.8	2	5	5	0.9	6.1	1.2	1.1	1.1	0
77	1	0	0	196	235	464	49.5	5	5	5	3.6	0.3	5.4	1.2	25.7	1,800
78	1	0	0	129	232	469	48.4	3	5	5	2.0	3.0	17.2	13.9	17.5	2,500
79	1	0	0	227	317	639	52.8	5	5	5	3.9	1.8	5.4	12.5	49.2	3,500
80	1	0	0	212	230	826	41.1	5	5	2	2.2	0.1	0.0	30.9	83.0	1,200
81	1	0	0	105	214	659	38.4	5	5	5	0.0	6.8	1.6	19.7	72.7	300
82	1	0	0	147	250	794	47.7	5	5	5	0.8	2.8	1.1	24.0	79.5	2,500
83	1	0	0	159	190	368	49.1	4	5	5	0.5	0.4	1.3	28.1	31.8	4,000
84	1	0	0	168	160	241	33.4	2	4	5	1.6	4.1	3.5	7.1	0.0	4,000
85	1	0	0	126	235	414	36.1	2	4	1	1.9	12.9	22.4	0.0	0.2	2,300
86	1	1	0	181	246	338	49.7	2	4	2	1.0	13.9	0.4	0.0	11.2	900
87	1	1	0	152	240	299	40.1	2	4	5	2.3	10.7	6.5	0.0	0.0	0
88	1	1	1	300	290	302	37.8	2	4	5	0.1	9.7	1.8	0.0	1.2	0
89	1	1	1	242	204	298	42.2	2	1	5	1.3	3.5	1.5	2.5	6.1	0
90	1	0	0	209	279	440	54.6	2	2	5	2.2	11.5	0.8	11.7	0.0	8,600

(continued)

Appendix I. (Continued).

91	1	0	0	159	270	367	49.9	3	1	5	5.2	5.7	9.9	0.2	0.0	8,500
92	1	0	0	289	273	303	51.8	4	5	1	0.4	0.4	2.6	13.5	0.0	6,000
93	1	0	0	262	253	322	48.3	4	5	5	0.2	2.0	2.1	17.5	0.0	5,000
94	1	0	0	165	269	331	51.2	4	1	5	0.3	4.5	2.9	13.4	0.0	2,500
95	1	0	0	234	230	445	46.0	4	3	5	0.6	0.8	4.0	29.9	0.0	4,000
96	1	0	0	136	187	458	46.1	4	3	5	1.8	1.2	6.2	38.8	0.0	4,000
97	1	0	0	183	256	506	40.0	3	3	5	2.2	2.8	9.6	29.8	0.0	8,000
98	1	0	0	147	220	467	47.7	4	1	5	0.6	0.6	8.7	33.8	0.0	9,000
99	1	1	0	177	201	384	41.5	4	5	4	0.7	0.1	7.1	28.6	1.2	6,000
100	1	1	1	154	177	252	34.9	4	4	5	0.7	1.6	4.5	7.4	0.8	2,000
101	1	0	0	251	219	317	44.1	4	4	5	0.0	1.2	1.2	7.5	3.1	2,500
102	1	0	0	196	214	300	37.3	4	4	4	0.5	0.9	4.3	21.1	0.0	1,900
103	1	0	1	195	262	311	37.8	4	4	5	1.0	5.0	4.9	7.2	3.2	1,100
104	1	0	1	141	183	342	36.6	5	5	1	0.4	4.5	5.8	1.3	22.9	65
105	1	0	0	140	144	287	26.9	5	5	2	1.9	3.0	4.0	0.0	11.5	250
106	1	0	0	177	183	195	26.4	2	5	5	0.3	9.6	0.3	2.0	5.8	350
107	1	0	0	110	183	421	28.0	5	5	5	0.6	3.9	0.6	10.4	32.8	1,550
108	1	0	0	60	169	573	29.6	5	5	5	0.8	0.5	0.9	29.5	49.3	100
109	1	0	0	104	164	573	36.6	5	5	5	1.4	0.0	0.1	17.0	73.1	100
110	1	0	0	116	216	860	43.5	5	5	5	4.7	2.4	0.8	19.8	101.9	0
111	1	0	0	92	159	811	33.1	5	5	5	0.9	0.7	0.1	1.8	121.3	250
112	1	0	0	79	175	646	37.5	5	5	5	7.2	1.4	0.6	2.6	82.6	0
113	1	1	1	171	144	317	38.2	5	2	5	4.7	0.0	0.2	2.0	28.0	800
114	1	1	1	201	189	403	39.5	3	5	4	0.8	7.4	7.2	16.6	0.0	0
122	2	1	0	107	189	693	42.5	5	3	5	1.1	1.0	1.1	3.8	103.6	0
123	2	0	0	114	235	786	45.5	5	5	5	1.3	1.2	1.2	6.1	103.1	0
124	2	0	0	83	222	930	41.3	5	5	5	0.4	1.8	2.1	4.3	124.7	0
125	2	0	0	96	212	1,022	40.6	5	5	5	0.3	2.1	2.2	2.2	149.5	325
126	2	0	0	98	174	1,062	35.8	5	5	5	0.3	0.2	0.6	0.0	170.7	250
127	2	0	0	112	174	1,085	38.0	5	5	5	2.3	0.1	1.5	3.3	185.0	150
128	2	0	0	116	174	1,156	36.3	5	5	5	0.8	0.2	7.1	0.4	175.5	550
129	2	0	0	77	157	1,138	33.8	5	5	5	0.2	0.1	0.0	0.0	179.2	600
130	2	0	0	92	257	830	38.3	5	5	5	0.4	0.1	4.6	0.0	176.5	1,250
131	2	0	0	159	195	597	40.2	5	5	5	0.0	0.0	7.4	0.0	61.9	0
132	2	1	1	160	170	378	48.2	5	5	5	1.3	1.9	4.6	5.3	26.7	0

(continued)

Appendix I. (Continued).

133	2	0	0	145	182	456	40.3	5	5	5	1.3	0.8	3.6	0.0	48.5	2,000
134	2	0	0	87	211	541	45.2	5	5	5	0.9	0.5	1.7	8.8	55.3	1,300
135	2	0	0	123	223	752	38.4	5	5	5	1.1	0.6	1.2	21.6	74.4	1,500
136	2	0	0	158	233	811	43.9	5	5	5	0.1	0.6	6.7	0.5	99.4	500
137	2	0	0	124	222	473	44.3	3	5	5	0.2	2.0	18.3	1.1	43.3	1,000
138	2	0	0	154	139	436	34.5	5	5	5	0.2	0.1	5.1	5.8	50.1	3,500
139	2	0	0	173	195	396	38.8	5	5	5	0.7	2.0	5.0	0.0	34.4	1,000
140	2	0	0	184	178	327	41.7	5	5	5	0.3	0.1	1.3	0.1	20.1	4,500
141	2	0	0	172	142	185	35.8	3	5	5	0.4	0.1	5.2	3.9	1.0	6,500
142	2	0	0	238	229	253	37.2	2	5	5	1.7	3.4	0.7	0.0	0.0	3,000
143	2	0	0	228	139	206	41.5	3	5	5	1.6	1.5	0.0	0.0	0.0	5,000
144	2	0	0	232	212	371	46.1	4	5	5	2.5	0.5	0.3	7.7	4.2	2,300
145	2	1	1	239	232	262	31.7	2	5	5	0.1	3.8	0.4	4.8	0.0	100
146	2	1	1	141	256	476	46.4	5	5	5	1.5	2.6	3.7	0.0	28.5	2,500
147	2	0	0	91	402	799	35.4	5	5	5	0.7	0.9	4.8	5.7	91.2	2,000
148	2	0	0	146	187	402	31.4	5	5	5	0.3	0.5	0.1	6.5	29.0	0
149	2	0	0	116	123	500	33.8	5	5	5	0.6	1.2	0.0	4.9	55.8	0
150	2	0	0	73	188	661	36.9	5	5	5	0.0	0.6	1.4	10.5	87.8	0
151	2	0	0	111	183	732	34.7	5	1	5	0.3	1.6	1.4	2.4	94.2	0
152	2	0	0	89	244	719	43.6	5	1	5	0.9	0.3	7.9	0.0	99.5	0
153	2	0	0	98	219	982	39.9	5	5	5	0.7	0.2	5.4	0.0	134.1	0
154	2	0	0	104	280	994	51.8	5	5	5	0.1	0.2	0.0	2.0	155.5	0
155	2	0	0	98	273	1,335	43.7	5	5	1	0.6	0.1	1.2	0.0	207.2	0
156	2	0	0	79	260	1,312	49.8	5	5	1	0.2	0.0	0.6	0.0	196.6	0
157	2	0	0	89	216	758	43.8	5	5	5	2.0	0.2	0.1	1.5	111.2	0
158	2	0	0	95	197	766	41.3	5	5	5	0.8	0.4	16.4	0.0	77.6	1,800
159	2	0	0	64	155	875	34.5	5	5	5	0.7	0.9	33.8	1.0	99.7	0
160	2	0	0	110	170	707	32.3	5	5	5	0.4	2.1	2.5	17.9	87.3	900
161	2	0	0	73	139	712	33.5	5	5	5	2.5	0.2	0.1	1.1	116.1	600
162	2	1	1	183	238	287	52.0	5	5	5	0.2	1.1	0.0	8.5	18.9	200
163	2	1	1	160	184	355	39.2	5	5	5	1.1	0.0	1.3	1.1	30.9	0
164	2	0	0	167	264	490	47.5	5	4	5	0.0	0.1	1.2	3.7	36.6	0
165	2	0	0	247	239	407	50.1	5	5	5	1.1	5.9	1.0	0.9	17.2	0
166	2	0	0	260	260	260	50.3	5	5	1	0.9	0.8	2.5	2.3	10.0	0
167	2	0	0	228	238	334	41.8	4	5	1	3.2	1.0	0.1	10.1	13.5	0

(continued)

Appendix I. (Continued).

168	2	0	0	190	219	478	41.0	5	1	5	3.6	0.9	0.0	2.2	39.7	3,000
169	2	0	0	151	104	116	27.7	1	5	5	3.6	0.0	0.0	3.8	0.0	200
170	2	0	0	117	192	278	29.2	2	5	5	0.9	6.7	0.0	4.4	0.0	0
171	2	0	0	159	147	166	31.1	4	4	5	1.3	0.2	0.0	5.5	0.0	0
314	3	0	0	62	80	364	13.1	3	5	4	6.0	0.0	3.0	40.4	9.4	0
315	3	0	0	46	111	417	14.1	3	4	4	8.5	0.0	26.4	7.9	1.0	0
316	3	0	0	156	115	164	22.5	4	5	4	2.5	0.0	0.0	2.8	0.0	400
317	3	0	0	95	68	104	17.0	4	5	4	1.6	1.6	2.1	0.0	0.0	1,800
318	3	0	0	81	52	52	14.1	1	5	4	2.4	0.2	1.1	0.0	0.0	0
319	3	0	0	70	104	167	13.5	4	5	4	5.7	0.0	0.4	30.8	2.7	3,000
320	3	0	0	52	98	586	15.9	4	5	4	2.9	0.1	0.0	87.6	0.3	1,000
321	3	0	0	85	93	353	21.4	4	5	4	1.5	0.3	0.4	63.0	0.0	25
322	3	0	0	82	82	324	17.8	4	4	1	5.1	1.1	0.2	47.3	0.0	1,600
323	3	0	0	55	74	458	15.4	4	5	4	3.2	0.7	0.4	57.6	0.0	1,000
324	3	0	0	178	111	161	26.4	4	5	5	2.1	0.0	1.1	6.4	0.0	2,500
325	3	0	0	82	94	272	23.4	4	5	5	0.3	0.0	3.9	19.7	5.1	2,000
326	3	0	0	79	107	335	20.6	5	4	5	0.0	0.0	2.6	3.4	30.5	1,500
327	3	0	0	86	72	81	16.6	2	3	4	0.0	0.6	0.5	2.0	0.0	1,600
328	3	0	0	74	79	98	15.4	4	4	4	0.0	0.3	2.7	0.0	0.0	3,000
329	3	0	0	64	55	201	13.8	5	4	3	0.0	0.0	1.0	0.0	14.4	8,000
330	3	0	0	73	31	31	9.8	5	4	3	0.2	0.0	0.5	0.0	0.9	3,000
331	3	0	0	70	61	61	10.7	4	4	3	0.0	0.0	0.7	0.0	0.0	5,000
332	3	0	0	70	43	43	11.0	4	4	3	0.0	0.0	3.0	0.0	0.0	1,200
333	3	0	0	92	86	104	17.7	3	4	4	0.0	0.0	4.3	2.3	0.0	2,500
334	3	0	0	85	116	190	17.0	4	4	4	0.0	0.0	5.5	9.3	0.0	6,000
335	3	0	0	166	166	166	26.4	4	4	3	0.0	0.0	3.9	4.0	0.0	6,000
336	3	0	0	101	165	251	18.7	3	5	3	0.8	0.0	17.4	0.0	0.0	5,000
337	3	1	1	128	67	67	19.5	3	5	4	0.3	0.6	6.3	0.0	0.0	2,500
338	3	0	0	61	91	214	21.1	3	5	4	0.4	1.8	24.0	5.8	0.0	1,000
339	3	0	0	62	100	415	19.9	4	5	4	0.3	0.1	5.9	52.3	0.0	1,000
340	3	0	0	52	89	463	22.9	4	5	4	0.0	0.1	7.9	80.4	0.0	1,500
341	3	1	1	8[illegible]	117	806	21.0	4	5	1	0.3	0.0	7.8	67.6	1.6	1,000
342	3	0	0	61	104	827	18.0	4	5	4	32.3	0.2	0.0	61.1	15.8	900
343	3	0	0	82	109	687	26.2	4	5	3	61.7	0.0	0.0	34.1	32.3	1,100
344	3	0	0	133	96	96	19.3	3	1	4	19.1	1.1	2.9	0.0	0.0	600

(continued)

Appendix I. (Continued).

345	3	0	0	79	73	73	15.6	4	4	4	0.1	2.1	0.1	10.1	0.0	700
346	3	0	0	68	80	342	19.3	4	4	1	0.0	0.0	0.0	45.7	0.0	3,000
347	3	0	0	117	160	418	18.1	4	4	4	0.1	0.0	0.0	38.9	0.0	1,000
348	3	0	0	95	123	304	23.0	4	4	1	0.0	0.8	0.0	32.3	0.6	0
349	3	1	1	99	86	86	21.2	4	5	4	0.0	0.2	0.5	1.0	0.0	0
350	3	0	0	64	104	216	15.4	5	5	4	0.0	0.0	0.0	0.0	19.3	0
351	3	0	0	106	87	242	17.0	5	5	1	0.0	0.0	0.1	0.0	18.9	0
352	3	0	0	108	86	86	19.1	5	1	5	0.0	0.0	0.2	0.0	4.4	0
353	3	0	0	135	165	232	24.2	5	1	5	1.1	0.0	0.1	0.6	16.1	0
354	3	0	0	151	157	516	22.7	5	1	2	0.0	0.0	0.0	0.0	58.5	0

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[a] ID - identification number of half-mile segments; segments are numbered from east to west.
AREA - staging area in which river segment is located.
ROAD - presence (1) or absence (0) of road immediately adjacent to river.
BRIDGE - presence (1) or absence (0) of bridge crossing over the river segment.
WIDTH - width (m) of widest unobstructed channel within river segment.
CHANNOW - total width (m) of water at mid-point of river segment.
BANKBANK - distance (m) from North bank to South bank of present river channel at mid-point of segment.
AREANOW - area (acres) of water within river segment.
HTBANK - height class[b] of predominant vegetation along island banks.
HTNORTH - height class of predominant vegetation along North bank of channel.
HTSOUTH - height class of predominant vegetation along South bank of channel.
I1 - acreage of island vegetation of height class 1.
I2 - acreage of island vegetation in height class 2.
I3 - acreage of island vegetation in height class 3.
I4 - acreage of island vegetation in height class 4.
I5 - acreage of island vegetation in height class 5.
CRANES - maximum number of cranes seen roosting on river segment during 1979.

[b] Vegetation height classes are as follows:
(1) less than 0.5 m.
(2) 0.5 m to 1.9 m.
(3) 2.0 m to 3.9 m.
(4) 4.0 m to 7.9 m.
(5) 8.0 m and over.

Appendix J. Confirmed sightings of whooping cranes in the Rainwater Basin Area, 1950 - spring 1980.

Date	Location	No. cranes
Spring		
10 April 1969	4 mi. N. and 4 mi. W. of Minden (Kearney Co.) SE 1/4, S19, T6N, R15W	1A[a]
8 April 1970	4 mi. S. of Upland (Franklin Co.)	2A
11 April 1973	3 1/2 mi. S. and 1 1/2 mi. E. of Upland (Franklin Co.) S35 or 36, T4N, R14W	2A
17-19 April 1975	Funk Lagoon,[b] 3 mi. N. and 1 1/2 mi. E. of Funk (Phelps Co.) S2, T6N, R17W	9A
8-9 April 1979	Moses Hill wetland,[b] 4 mi. NNW of Holdredge (Phelps Co.) S3, T6N, R19W	4A
2 April 1980	5 mi. S. and 2 mi. W. of Minden (Kearney Co.) (near NE Sacramento Basin State Area) NW 1/4, S11, T5N, R15W	2A
7-8 April 1980	South Funk wetland, 1 1/2 mi. N. and 1/2 mi. E. of Funk (Phelps Co.) SE 1/4, S16, T6N, R17W	7A
Fall		
17 October 1960	SE Sacramento State Mgmt. Area,[b] 1 1/2 mi. S. and 2 mi. W. of Wilcox (Harlan Co.) S2 and 3, T4N, R17W	2A, 1J
11 October 1967	Peterson WPA, 3 mi. S. of Bertrand (Gospher Co.) probably S13, T6N, R21W	2U
26 October - 10 November 1971	Bluestem Marsh,[b] 1 mi. S. and 4 mi. E. of Axtell (Kearney Co.) SE 1/4, S19, T6N, R15W	2A, 1J
19 November 1973	1 1/2 mi. S. and 1 mi. E. of Kenesaw (Adams Co.) S2, T17N, R12W	3A
25 November 1974	Funk Lagoon,[b] 3 mi. N. and 1/2 mi. E. of Funk (Phelps Co.) S2, T6N, R17W	2A

[a] A = adult, J = juvenile, U = unidentified.

[b] Avian cholera outbreaks recorded at this site.

Appendix K. Estimated numbers of sandhill cranes using waterfowl production areas (WPA's) in the Rainwater Basin Area of south central Nebraska.

WPA	Date	Estimated no. cranes
Harvard	4 March 1977	450
	7 March 1977	500
	10 March 1977	300
	22 March 1977	450
	26 March 1977	600
	31 March 1977	350
	6 April 1977	450
	12 April 1977	100
	29 March 1978	75
Massie	7 March 1977	50
	22 March 1977	300
	26 March 1977	350
	31 March 1977	100
	6 April 1977	50
McMurtrey	22 March 1977	100
	26 March 1977	200
	31 March 1977	200
	6 April 1977	200
	12 April 1977	250
Clark	22 March 1977	200
Hansen	31 March 1977	50
	6 April 1977	35
Prairie Dog	10 October 1980	75

Appendix L. Effects of woody vegetation encroachment on abundance and distribution of various species of birds breeding in the Platte River Valley. Symbols denote increase (+), decrease (-) or no change (o).

Species	Impact of encroachment on	
	Abundance	Distribution
Bobwhite	+	+
Piping Plover	-	-
Killdeer	o	o
Upland Sandpiper	-	o
Spotted Sandpiper	-	o
Wilson's Phalarope	-	-
Least Tern	-	-
Yellow-billed Cuckoo	+	+
Great Horned Owl	+	o
Common Flicker	+	o
Red-bellied Woodpecker	+	+
Red-headed Woodpecker	+	o
Hairy Woodpecker	+	+
Downy Woodpecker	+	+
Eastern Kingbird	+	+
Western Kingbird	+	+
Great Crested Flycatcher	+	+
Willow Flycatcher	+	+
Eastern Wood Pewee	+	+
Western Wood Pewee	+	+
Blue Jay	+	+
Black-capped Chicadee	+	+

(continued)

Appendix L. (Continued).

House Wren	+	o
Gray Catbird	+	+
Brown Thrasher	+	o
American Robin	+	o
Starling	+	+
Bell's Vireo	+	+
Red-eyed Vireo	+	+
Warbling Vireo	+	+
Yellow Warbler	+	+
Common Yellowthroat	+	o
Bobolink	-	-
Eastern Meadowlark	-	-
Western Meadowlark	-	o
Orchard Oriole	+	+
Northern Oriole	+	+
Cardinal	+	+
Rose-breasted Grosbeak	+	+
Black-headed Grosbeak	+	+
Indigo Bunting	+	+
American Goldfinch	+	o
Dickcissel	-	-
Rufous-sided Towhee	+	o
Grasshopper Sparrow	-	o
Field Sparrow	+	+
Song Sparrow	o	o

Appendix M. Summary of the vegetation types on the Platte River floodplain.

Type	General description
SANDBAR	
Annual Sandbar	Recently exposed areas along the river channel colonized by sedge, spikerush, and other annuals.
Perennial Sandbar	Partially exposed areas near the river channel characterized by 1-2 m high cottonwood, willow, and dogwood saplings.
MEADOW	
Marsh	Cattail and hardstem bulrush dominated communities in pools of standing water near river channels and in the backwaters of major dams and diversions.
Lowland Grassland	Grazed, intermittently wet meadows dominated by ragweed, sedge, bluegrass, and a variety of other grasses. Low-lying areas are dominated by bulrush, spikerush, and frog fruit.
Upland Grassland	Dry meadows characterized by bluestem prairie, sandy areas dominated by cheatgrass and grasslands with scattered indigo bush shrub.
SHRUB	
Wetland Shrub	Riverbank and island shrub dominated by sandbar willow and indigo bush, with an understory of sedges, rushes, and American bugleweed in intermittently flooded areas, and an understory of goldenrod and cordgrass on drier island sites.
Upland Shrub	Indigo bush and rough-leaf dogwood dominated upland shrub areas in forest openings and along raised riverbanks. Common ragweed, Japanese brome and open ground are common in the understory.

(continued)

Appendix M. (Continued).

FOREST

Cottonwood/Willow Wetland	Intermittently flooded forest dominated by diamond willow, cottonwood, and green ash, with an understory of indigo bush, dogwood, and sandbar willow shrub. Frog fruit and sedge are important herbaceous species.
Cottonwood/Russian Olive	Wet forest areas dominated by either dense Russian olive with an overstory of scattered cottonwood, or dense cottonwood with Russian olive in the understory. Ragweed, sedge, and bluegrass are the dominant herbaceous species.
Cottonwood Meadow	Upland cottonwood forest with a grassland understory dominated by switchgrass, cordgrass, bluegrass, sand dropseed, bromegrass, and scattered low indigo bush, dogwood, and wild rose shrub.
Cottonwood/Red Cedar	Dry upland forest dominated by either dense red cedar with an overstory of scattered cottonwood, or dense cottonwood with red cedar in the understory. Green ash (seedlings), wild rose, poison ivy, and ragweed are the dominant ground cover species.
Mixed Hardwood Shrub	Moderately dry forest dominated by cottonwood with an understory of green ash, diamond willow, red mulberry, and American elm. Rough-leaf dogwood, indigo bush, and sandbar willow are the dominant shrubs, whereas goldenrod, poison ivy, bluegrass, and Canada wild rye are the major herbaceous species.

Appendix N. Average percent cover of the principal species composing the major habitat types on the floodplain of the North Platte and Platte Rivers. Species with average cover values <2% have not been included. The habitat types are as follows: annual sandbar (AS), perennial sandbar (PS), marsh (M), lowland grassland (LG), upland grassland (UG), wetland shrub (WS), upland shrub (US), cottonwood-willow wetland (CWW), cottonwood-Russian olive (CRO), cottonwood-red cedar (CRC), cottonwood-meadow (CM), and mixed hardwood shrub (MHS).

Common name	Habitat type											
	AS	PS	M	LG	UG	WS	US	CWW	CRO	CRC	CM	MHS
American Bugleweed						4.6						
American Bulrush		3.5	26.2	15.6				3.9	4.9			
American Elm										4.5		5.0
Aster						5.4						
Barnyard Grass	8.1											
Big Bluestem					11.0							
Bluegrass				16.4	10.2		12.8		21.4	24.5	17.1	7.1
Buckbrush				3.7	2.3					7.6		4.5
Bundleflower				2.5	6.0		3.1					
Canada Goldenrod						4.4		2.7				6.3
Canada Sanicle												4.2
Canada Wild Rye											4.2	2.9
Cattail			23.3									

(continued)

Appendix N. (Continued).

Cheatgrass				3.3	18.7		7.0			6.9	5.1	3.7
Climbing Bittersweet												3.5
Cocklebur	17.0	14.8				3.2						
Common Mullein					4.0	2.9						
Common Ragweed		5.5		16.2	18.5	18.1	8.5	7.4	21.1	5.8	14.9	
Cottonwood		5.1				8.5	8.7	27.6	29.8	36.2	34.4	28.9
Dandelion				3.5					4.0			
Diamond Willow		5.1				6.9	3.1	13.4	5.7		4.1	4.9
Foxtail Barley				5.0					2.6			
Frog Fruit			4.0	8.9		7.5		8.9	4.8			
Green Ash								6.8	7.2	7.1	4.5	10.3
Ground Cherry											2.4	
Hackberry												3.1
Hardstem Bulrush			38.4			4.2						
Hoary Vervain				2.2								
Hopseed									3.0	3.4	2.2	
Indigo Bush		3.6		8.8	7.0	21.5	20.5	4.8		4.0	9.0	4.3
Ironweed						3.0			2.7			

(continued)

Appendix N. (Continued).

Japanese Brome				3.4	13.8	4.2	5.9				8.3	
Lady's Thumb		3.4		5.7								
Little Bluestem					3.1							
Loosestrife		4.1		5.9					5.9			
Lovegrass	21.5											
Nutsedge	18.0											
Pale Smartweed		6.4										
Plains Sunflower					2.7	2.5					3.2	
Poison Ivy							6.6			11.5	2.5	20.5
Prairie Cordgrass		4.1			8.6	9.5	7.6	4.0	3.2	2.4	9.8	3.3
Prairie Dogbane						2.6				2.0		
Prickly Ash										5.4		3.1
Red Cedar							5.0		5.5	18.7	3.4	5.3
Red Clover				6.6								
Red Mulberry										5.5		4.4
Red Osier						3.7		2.1		2.0		2.0
Redtop				8.0								
Reed Canarygrass				7.1								

(continued)

Appendix N. (Continued).

Rough-leaved Dogwood							21.0	5.6	5.3	25.4	11.0	34.3
Russian Olive									18.4	6.2		2.2
Saltgrass				4.2	5.3			11.4				
Sandbar Willow	3.9	12.5	5.6	9.3		38.5	8.0	12.5				
Sand Dropseed	5.1				6.3					3.6		7.6
Sedge			10.0	10.3		9.8	7.9	11.5	7.2			
Slippery Elm												4.6
Small Panic Grass					2.7				3.2			
Smooth Brome				2.8	7.2							
Smooth Sumac												
Snow-on-the-Mountain					2.1							
Spikenard										3.0		2.7
Spikerush		17.1	10.7	9.4		4.2		4.7				
Spotted Spurge					2.9							
Switchgrass				6.9	6.7		10.4		2.8		4.9	
Wheatgrass				5.0	8.0		3.3		5.9			
White Sweet Clover		3.2		3.3	2.9		6.3			3.3	4.6	
Wild Grape					2.0	3.9		4.1	3.1	5.1	2.8	4.8

(continued)

Appendix N. (Continued).

Wild Rose	5.1	4.0	5.8	3.3	3.7
Woodbine			2.6		4.5

Appendix O. Average and earliest years of establishment of cottonwood, red cedar, willow, and other trees along the Platte River as determined by increment tree cores. Tree age (relative to 1979) is provided in parentheses following each year.

Location		Cottonwood		Red cedar		Willow		Other	
		Average	Earliest	Average	Earliest	Average	Earliest	Average	Earliest
Feltz	402-01	1945 (34)	1940 (39)	1954 (25)	1941 (38)	-- --	-- --	-- --	-- --
Feltz	402-02	1929 (50)	1923 (56)	-- --	-- --	-- --	-- --	-- --	-- --
Buckhorn	391-08	1941 (38)	1939 (40)	1966 (13)	1963 (16)	1954 (25)	1954 (25)	-- --	-- --
Boyle	337-01	1937 (42)	1934 (45)	-- --	-- --	1934 (45)	1934 (45)	-- --	-- --
Boyle	337-03	1937 (42)	1930 (49)	-- --	-- --	1934 (45)	1934 (45)	1952 (27)	1952 (27)[a]
Summers	335-11	1919 (60)	1918 (61)	-- --	-- --	-- --	-- --	-- --	-- --
Star	327-10	1939 (40)	1933 (46)	-- --	-- --	1952 (27)	1952 (27)	-- --	-- --
Applegate	320-02	1930 (49)	1923 (56)	-- --	-- --	-- --	-- --	-- --	-- --
Applegate	320-04	1944 (35)	1940 (39)	-- --	-- --	1948 (31)	1944 (35)	-- --	-- --
Cofer	312-13	1944 (35)	1921 (58)	-- --	-- --	-- --	-- --	-- --	-- --
Golden	301-05	1952 (27)	1951 (28)	-- --	-- --	1951 (28)	1951 (28)	-- --	-- --
Golden	301-06	1967 (12)	1967 (12)	-- --	-- --	-- --	-- --	-- --	-- --
Maxwell	282-05	1949 (30)	1948 (31)	1963 (16)	1963 (16)	-- --	-- --	-- --	-- --
Maxwell	282-02	-- --	-- --	1942 (37)	1942 (37)	1959 (20)	1959 (20)	-- --	-- --
Martin	277-06	1915 (64)	1900 (79)	1938 (41)	1924 (55)	-- --	-- --	-- --	-- --

(continued)

Appendix O. (Continued).

Brady	266-03	1936 (43)	1927 (52)	1956 (23)	1949 (30)	-- --	-- --	-- --	-- --
Brady	266-05	1906 (73)	1894 (85)	1931 (48)	1926 (53)	-- --	-- --	-- --	-- --
Gothenburg	245-06	1942 (37)	1935 (44)	1952 (27)	1940 (39)	1943 (36)	1943 (36)	-- --	-- --
Koch	229-05	1936 (43)	1929 (50)	1952 (27)	1940 (39)	1926 (53)	1926 (53)	-- --	-- --
Cozad	219-13	1937 (42)	1932 (47)	1950 (29)	1944 (35)	-- --	-- --	-- --	-- --
Darr	208-03	1943 (36)	1924 (55)	1938 (41)	1938 (41)	-- --	-- --	-- --	-- --
Darr	208-09	1951 (28)	1949 (30)	-- --	-- --	-- --	-- --	-- --	-- --
Lexington	188-01	1949 (30)	1945 (34)	-- --	-- --	-- --	-- --	-- --	-- --
Lexington	188-06	1939 (40)	1936 (43)	-- --	-- --	-- --	-- --	-- --	-- --
Jeffrey	172-06	1908 (71)	1907 (72)	-- --	-- --	-- --	-- --	-- --	-- --
Jeffrey	172-05	1956 (23)	1956 (23)	-- --	-- --	-- --	-- --	-- --	-- --
Jeffrey	171-07	1940 (39)	1934 (45)	-- --	-- --	-- --	-- --	-- --	-- --
Jeffrey	166-05	1948 (31)	1929 (50)	-- --	-- --	-- --	-- --	-- --	-- --
Peterson	160-02	1942 (37)	1928 (51)	-- --	-- --	-- --	-- --	-- --	-- --
Peterson	158-04	1934 (45)	1917 (62)	-- --	-- --	-- --	-- --	-- --	-- --
Peterson	156-05	1913 (66)	1903 (76)	1953 (26)	1940 (39)	1925 (54)	1919 (60)	-- --	-- --
Peterson	156-08	1941 (38)	1933 (46)	1962 (17)	1962 (17)	1916 (63)	1916 (63)	-- --	-- --
McCormick	139-02	-- --	-- --	1937 (42)	1936 (43)	-- --	-- --	-- --	-- --

(continued)

Appendix O. (Continued).

McCormick	139-05	1955 (24)	1952 (27)	1958 (21)	1958 (21)	-- --	-- --	-- --	-- --
Odessa	122-07	1954 (25)	1943 (36)	1968 (11)	1966 (13)	-- --	-- --	-- --	-- --
Odessa	122-11	1944 (35)	1942 (37)	1957 (22)	1956 (23)	-- --	-- --	-- --	-- --
Volentine	119-06	1955 (24)	1951 (28)	-- --	-- --	-- --	-- --	-- --	-- --
Volentine	119-16	1936 (43)	1934 (45)	1960 (19)	1959 (20)	-- --	-- --	-- --	-- --
Johnson	111-09	-- --	-- --	1949 (30)	1949 (30)	-- --	-- --	-- --	-- --
Kahle	109-05	1962 (17)	1961 (18)	-- --	-- --	-- --	-- --	-- --	-- --
Kahle	109-06	1943 (36)	1929 (50)	1960 (19)	1957 (22)	-- --	-- --	-- --	-- --
Camp	106-06	1887 (92)	1881 (98)	1922 (57)	1916 (63)	-- --	-- --	-- --	-- --
Bassway	97-02	1930 (49)	1929 (50)	1957 (22)	1951 (28)	-- --	-- --	-- --	-- --
Bassway	97-03	1945 (34)	1945 (34)	-- --	-- --	-- --	-- --	-- --	-- --
Bassway	97-05	1916 (63)	1915 (64)	1960 (19)	1957 (22)	-- --	-- --	-- --	-- --
Audubon	92-02	1916 (63)	1914 (65)	-- --	-- --	-- --	-- --	-- --	-- --
Audubon	92-03	1969 (10)	1969 (10)	-- --	-- --	-- --	-- --	-- --	-- --
Audubon	91-15	1943 (36)	1937 (42)	-- --	-- --	1927 (52)	1927 (52)	-- --	-- --
Woodman	75-11	1947 (32)	1938 (41)	-- --	-- --	-- --	-- --	-- --	-- --
Woodman	75-15	1960 (19)	1960 (19)	-- --	-- --	-- --	-- --	-- --	-- --
Short	68-04	1921 (58)	1919 (60)	1949 (30)	1949 (30)	-- --	-- --	-- --	-- --

(continued)

Appendix O. (Continued).

Short	68-12	1960 (19)	1960 (19)	1963 (16)	1963 (16)	-- --	-- --	-- --	-- --
Mormon	44-04	1936 (43)	1936 (43)	-- --	-- --	-- --	-- --	-- --	-- --
Mormon	44-06	1903 (76)	1890 (89)	1955 (24)	1955 (24)	-- --	-- --	-- --	-- --
Mormon	42-13	-- --	-- --	1956 (23)	1943 (36)	1934 (45)	1934 (45)	1950 (29)	1950 (29)[b]
Mormon	42-11	1961 (18)	1961 (18)	1962 (17)	1962 (17)	1940 (39)	1940 (39)	-- --	-- --
Baim	8-09	1951 (28)	1943 (36)	-- --	-- --	-- --	-- --	-- --	-- --
Boerson	4-01	1936 (43)	1931 (48)	1952 (27)	1952 (27)	-- --	-- --	1940 (39)	1940 (39)[c]
Boerson	4-03	1957 (22)	1957 (22)	1965 (14)	1965 (14)	1960 (19)	1960 (19)	-- --	-- --
Boerson	4-01	1918 (61)	1918 (61)	-- --	-- --	-- --	-- --	-- --	-- --
Chapman	1-04	1954 (25)	1954 (25)	1960 (19)	1957 (22)	-- --	-- --	-- --	-- --

---

[a] Russian olive.

[b] Hackberry.

[c] Catalpa.

Appendix P. The relationship between vegetation and soils at selected sites along the North Platte and Platte Rivers. The dominant vegetation, soil type, pH, and the surface and subsurface soil texture are presented for each location.

Location		Vegetation	Surface pH	Surface texture	Subsoil texture	Soil type
Keystone	404-02	Cottonwood/ Red cedar	7.6	Silty loam	Sand/Gravel	Platte
Boyle	337-01	Russian olive/ Cottonwood	8.2	Loam/Sandy loam	Sandy loam	McGrew
Boyle	337-1A	Bulrush/ Spikerush	7.5	Loam	Sand/Gravel	Platte
Boyle	337-03	Russian olive/ Cottonwood	7.6	Sandy loam	Loam/Clay loam	LAS
Applegate	320-04	Cottonwood/ Sedge	8.0	Loam	Sand/Gravel	Platte
Applegate	320-06	Cattail/ Bulrush	5.5	Loam	Sand/Gravel	Platte
Maxwell	280-00	Bromegrass/ Bluegrass	6.6	Loam	Sand/Gravel	Platte
Maxwell	280-00	Red cedar/ Cottonwood	7.1	Silty loam	Very fine sandy loam	Haverson
Cozad	219-08	Cottonwood/ Red cedar	7.5	Silty loam	Silty loam	Leshara

... ..(continued)

Appendix P. (Continued).

Cozad	219-10	Cottonwood (Dead)	7.1	Sandy loam	Sandy loam	Cass
Cozad	219-14	Diamond willow	7.7	Loamy sand	Fine sand/ Loam	Boel/River overwash
Lexington	188-01	Cottonwood (Open)	7.4	Loamy sand (lt. color)	Loamy sand	Inavale
Jeffrey	172-07	Cottonwood (Open)	6.9	Sand	Coarse sand	River overwash
Jeffrey	165-00	Cottonwood/ Dogwood	5.8	Sandy loam	Silt loam/ Sandy loam	Darr
Overton	163-00	Bluestem (Hayfield)	7.5	Silt loam	Silt loam	Leshara
Overton	163-00	Best grasses Russian olive	7.7	Silty clay loam	Silty clay loam	Lamo
Odessa	122-05	Cottonwood (Open)	5.8	Sandy loam	Find sand	Boel
Odessa	122-11	Cottonwood/ Red cedar	5.5	Sandy loam	Sandy loam	Darr
Camp	106-06	Bromegrass/ Bluegrass	6.4	Sandy loam	Sand/Gravel	Platte
Camp	106-06	Red cedar/ Cottonwood	7.0	Silt loam	Silt loam	Leshara
Bassway	97-02	Cottonwood/ Red cedar	6.6	Silt loam	Silty clay loam	Grigston

(continued)

Appendix P. (Continued).

Audubon	92-01	Russian olive/ Bluegrass	8.0	Silty clay loam	Silty clay loam	Lamo
Audubon	92-1A	Sedge (Marsh)	6.0	Silty clay loam	Silty clay loam	Lamo
Audubon	91-01	Cottonwood/ Dogwood	7.3	Loam	Coarse Gravel/Sand	Platte
Audubon	91-03	Sandbar willow	6.4	Sandy loam	Fine sand	Boel
Audubon	91-06	Cocklebur (Sandflat)	7.3	Sand	Sand/Gravel	Sandy Alluvial
Audubon	90-05	Bluestem (Prairie)	6.9	Silt loam	Silt loam	Hobbs
Gibbon	89-00	Russian olive/ Bluegrass	6.9	Silty clay loam	Sandy silt clay loam	Lamo
Woodman	75-02	Cottonwood/ Dogwood	7.3	Silt loam	Silt loam	Leshara
Woodman	75-15	Cottonwood (Young)	5.9	Sandy loam	Fine sand	Boel
Shoemaker	54-00	Bluestem (Hayfield)	8.1	Silt loam	Silt loam	Grigston
Shoemaker	50-00	Redtop (Grazed)	7.1	Silt loam	Silt loam	Leshara
Mormon	41-01	Bromegrass (Hayfield)	7.9	Silt loam	Silt loam	Leshara

(continued)

Appendix P. (Continued).

Mormon	41-02	Redtop (Grazed)	6.6	Sandy loam	Sandy loam	Wann
Chapman	1-00	Sandbar willow	7.6	Loamy sand (lt. color)	Loamy sand	Inavale
Chapman	1-03	Diamond willow	7.0	Sandy loam	Sandy loam	Alda
Chapman	1-04	Cottonwood/ Red cedar	5.5	Sandy loam	Sandy loam	Cass

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Appendix Q. Definitions of the 12 environmental parameters used to characterize the 71 permanent quadrats in riparian vegetation studies.

Parameters	Definition
SOIL MOISTURE	
Average soil moisture	Average weekly % soil moisture between 10 June and 27 August.
Critical soil moisture	Average weekly % soil moisture between 16 July and 27 August.
Minimum soil moisture	Minimum weekly % soil moisture between 10 June and 27 August.
SOIL TEXTURE	
Coarse gravel	% soil fraction >4760 microns.
Gravel	% soil fraction 2000-4760 microns.
Sand	% soil fraction 250-2000 microns.
Very fine sand	% soil fraction 105-250 microns.
Silt	% soil fraction <105 microns.
WATER REGIME	
Exposure (days)	Number of days (out of 77) of no flooding between 16 July and 30 September.
Average depth (cm)	Average depth (cm) during flooding between 16 July and 30 September.
Total maximum (cm)	Maximum water depth between 10 June and 30 September.
Critical maximum (cm)	Maximum water depth between 16 July and 30 September.

Appendix R. Use of grasslands by whooping cranes.

Date	Location	Grassland type and description-activity
25 October 1978	Just west of Big Salt Marsh, Quivira NWR, Kansas	Overgrazed salt grass pasture. Believed to be drinking from small stream.
9 November 1978	Just west of Big Salt Marsh, Quivira NWR, Kansas	Closely grazed, small salt grass (*Distichlis*) pasture.
24-27 October 1977	6 1/2 mi. N and 2 1/2 mi. W of Shelton, Nebraska	Brome/native grass pasture of about 34 ha. Some apparent feeding activity was noted. Grass was very short.
4-7 November 1977	Within Valentine NWR, Nebraska	a. Sub-irrigated meadow of native grasses, mowed in the fall. Whooper foraged with sandhill cranes. Dense stems, some shoots up to 30 cm high.
		b. Used a second sub-irrigated meadow in same area. Native grasses, mowed in fall, dense stems, shoots 10 to 15 cm high. Fed with sandhill cranes.
23-25 October 1978	2 mi. E and 2 mi. N of Whitman, Nebraska	Sub-irrigated meadow of native grasses. Heights of grasses approached 61 cm in protected pockets; do not know how high grass was where cranes fed. Fed occasionally in the meadow.

Note: There are several additional observations of whooping cranes using sub-irrigated meadows, but neither the status of the meadow (i.e., height of vegetation) nor the behavior of the cranes was noted.

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Page	Description	Photographer
Frontispiece	Sandhill cranes in fog on the Platte River	Jan Eldridge
1	Sandhill cranes in flight	Jan Eldridge
4	Aerial view of Platte River	Jan Eldridge
5	Sandhill cranes in meadow	Jan Eldridge
8	Platte River	Jan Eldridge
15	Sandhill crane	Jan Eldridge
36	Whooping cranes in channel of Platte River	Larry O'Borney
46	Canada geese near Platte River	Jan Eldridge
53	Bald eagle perched on tree limb along the Platte River	Jan Eldridge
62	Least tern incubating clutch on sandbar in Platte River	Craig Faanes
69	Native meadow being tilled	Gary Lingle
82	Waterfowl victims of avian cholera in Rainwater Basin Area	Al Trout
96	Willow clump on sandbar in the Platte River	Gary Krapu
121	Platte River	Gary Krapu
Back cover	Vertical view of native meadows and sandhill cranes near the Platte River	Ed Ferguson

END

6-28-82